HUMAN

PHYSIOLOGY.

BY

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"Vastissimi studii primas quasi lineas circumscripsi."—HALLER.

WITH

NEARLY FIVE HUNDRED ILLUSTRATIONS.

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HUMAN PHYSIOLOGY.

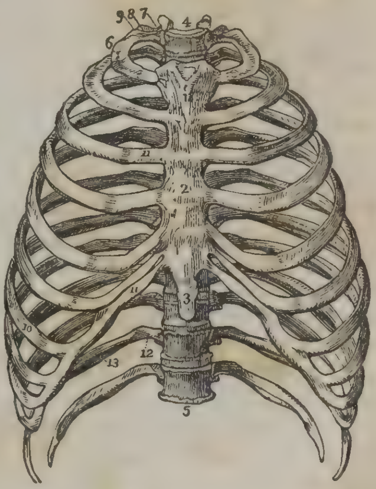
BOOK II.

CHAPTER III.

RESPIRATION.

The consideration of the function of absorption has shown how the different products of nutritive absorption reach the venous blood. By simple admixture with this fluid they do not become converted into a substance, capable of supplying the losses sustained by the frame from the different excretions. Nothing is better established than the fact, that no being, and no part of any being, can continue its functions unless supplied with blood, that has become *arterial* by exposure to air. It is in the lungs, that the absorbed matters undergo their final conversion into that fluid,—by a function, which has been termed *hæmatosis*, the great object of that which we have now to investigate—Respiration. This conversion is occasioned by the venous blood of the pulmonary vessels coming in contact with air in the air-cells of the lungs, during which the blood gives to the air some of its constituents, and, in return, the air parts with its elements to the blood.

Fig. 262.



Anterior View of Thorax.

1. Superior piece of sternum. 2. Middle piece. 3. Inferior piece, or ensiform cartilage. 4. First dorsal vertebra. 5. Last dorsal vertebra. 6. First rib. 7. Its head. 8. Its neck, resting against transverse process of first dorsal vertebra. 9. Its tuberosity. 10. Seventh or last true rib. 11. Costal cartilages of true ribs. 12. Two last false ribs — floating ribs. 13. The groove along lower border of rib for lodgment of intercostal vessels and nerve.

To comprehend this mysterious process, we must be acquainted with the pulmonary apparatus, as well as with the properties of atmospheric air, and the mode in which the contact between it and the blood is effected.

1. ANATOMY OF THE RESPIRATORY ORGANS.

The *thorax* or *chest* contains the lungs,—the great agents of respiration. It is of a conical shape, the apex of the cone being formed by the neck, and the base by a muscle, which has already been referred to more than once,—the *diaphragm*.

The osseous framework, Fig. 262, is formed, *posteriorly*, of twelve dorsal vertebræ; *anteriorly*, of the sternum, originally composed of eight or nine pieces; and *laterally*, of twelve ribs on each side, passing from the vertebræ to, or towards, the sternum. Of these, the seven uppermost extend the whole distance from the spine to the breast-bone, and are called *true* or *sternal*, and at times, *vertebro-sternal ribs*. They become larger as they descend, and are situate more obliquely in regard to the spine. The other five, called *false* or *asternal*, do not proceed as far as the sternum; the cartilages of three of them join that of the seventh true rib, whilst the two lowest have no union with those above them, and are, therefore, called *floating ribs*. These false ribs become shorter and shorter as we descend; so that the seventh true rib may be regarded as the common base of two cones, formed by the true and false ribs respectively.

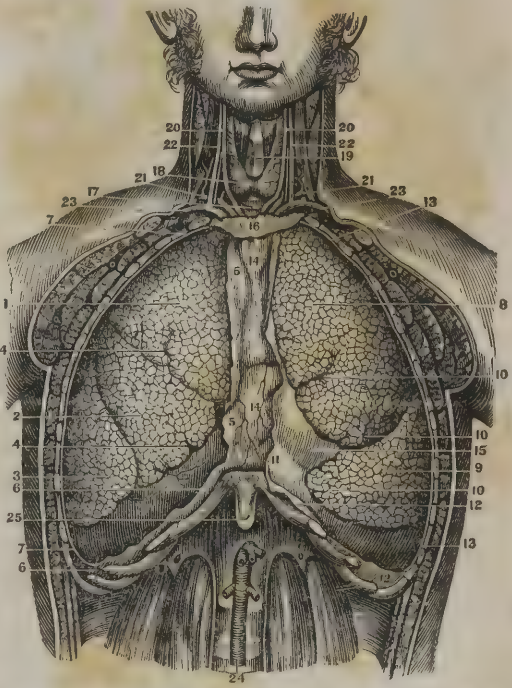
The different bones constituting the thorax are so articulated as to admit of motion, and thus of dilatation and contraction of the cavity. The motion of the vertebræ on each other has been described under another head. It is not materially concerned in the respiratory movements. The articulation of the ribs with the spine and sternum demands attention. They are articulated with the spine in two places, —at the *capitulum* or head, and at the *tubercle*. In the former of these, the extremity of the ribs, encrusted with cartilage, is received into a depression, similarly encrusted, at the side of the spine. One half of this depression is in the body of the upper vertebra; the other half in the one beneath it; and, consequently, partly in the intervertebral fibro-cartilage between the two. The joint is rendered secure by various ligaments; but it can move readily up and down on the spine. In the first, eleventh, and twelfth ribs, the articulations are with single vertebræ respectively. In the second articulation, the tubercle of the rib, also encrusted with cartilage, is received into a cavity in the transverse process of each corresponding vertebra; and the joint is rendered strong by three distinct ligaments. In the eleventh and twelfth ribs, this articulation is wanting. The articulation of the ribs with the sternum is effected by an intermediate cartilage, which becomes gradually longer, from the first to the tenth ribs, as seen in Fig. 262. The end of the cartilage is received into a cavity at the side of the sternum; and the junction is strengthened by an anterior and a posterior ligament. This articulation does not admit of much motion; but the existence of a synovial membrane shows, that it is destined for some.

The cavity of the thorax is completed by muscles. In the intervals between the ribs are two planes, whose fibres pass in inverse directions, and cross each other. These are the *intercostals*. The diaphragm forms the septum between the thorax and abdomen. Above, the cavity

is open; and through the opening numerous vessels and nerves enter. The muscles, concerned in the respiratory function, are numerous. The most important of them is the *diaphragm*. It is attached, by its circumference, around the base of the chest; but its centre rises into the thorax; and, during its state of relaxation, forms an arch, the middle of which is opposite the inferior extremity of the sternum. It is tendinous in its centre, and is attached by two fasciculi, called *pillars*, to the spine,—to the bodies of the first two lumbar vertebræ. It has three apertures; one before for the passage of the vena cava inferior; and two behind, between the pillars, for the passage of the œsophagus and aorta. The other great muscles of respiration are the *serratus posticus inferior*, *serratus posticus superior*, *levatores costarum*, *intercostal muscles*, *infra-costales*, and *triangularis sterni* or *sterno-costalis;* but, in an excited condition of respiration, all the muscles, that raise and depress the ribs, directly or indirectly, participate—as the *scaleni*, *sterno-mastoidei*, *pectoralis*, (*major* and *minor*,) *serratus major anticus*, *abdominal muscles*, &c.

In the structure of the *lungs*, as M. Magendie[1] has remarked, nature has resolved a mechanical problem of extreme difficulty. The problem was,—to establish an immense surface of contact between the blood and air, in the small space occupied by the lungs. The admirable arrangement adopted consists in this,—that each of the minute vessels, in which the pulmonary artery terminates and the pulmonary veins originate,

Fig. 263.

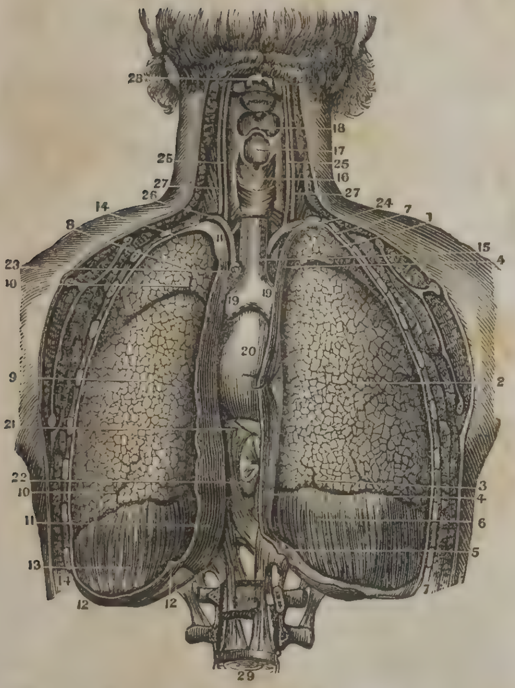


Anterior View of the Thoracic Viscera in situ, as shown by the removal of the Anterior Parietes of the Thorax.

1. Superior lobe of right lung. 2. Its middle lobe. 3. Its inferior lobe. 4, 4. Lobular fissures. 5, 5. Internal layer of costal pleura forming the right side of the anterior mediastinum. 6, 6. Right diaphragmatic portion of pleura costalis. 7, 7. Right pleura costalis on the ribs. 8. Superior lobe of left lung. 9. Its inferior lobe. 10, 10. Interlobular fissures. 11. Portion of pleura costalis which forms the left side of the anterior mediastinum. 12. Left diaphragmatic portion of pleura costalis. 13. Left pleura costalis. 14, 14. The middle space between the pleuræ, known as the anterior mediastinum. 15. Pericardium. 16. Fibrous partition over which the pleuræ are reflected. 17. Trachea. 18 Thyroid gland. 19. Anterior portion of thyroid cartilage. 20. Primitive carotid artery. 21. Subclavian vein. 22. Internal jugular vein. 23. Brachio-cephalic vein. 24. Abdominal aorta. 25. Xiphoid cartilage.

[1] Précis, &c., ii. 307.

Fig. 264.



Posterior View of the Thoracic Viscera, showing their relative positions by the removal of the Posterior Portion of the Parietes of the Thorax.

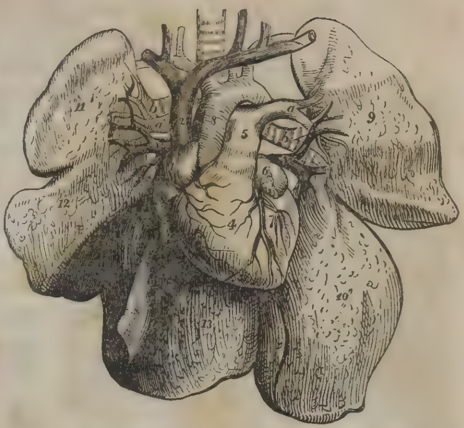
1, 2. Upper and lower lobes of right lung. 3. Interlobular fissures. 4. Internal portion of pleura costalis, forming one of the sides of posterior mediastinum. 5. Twelfth rib and lesser diaphragm. 6. Reflection of the pleura over the greater muscle of the diaphragm on the right side. 7, 7. Right pleura costalis adhering to the ribs. 8. 9 The two lobes of the left lung. 10, 10. Interlobular fissures. 11, 11. Left pleura, forming the parietes of the posterior mediastinum. 12, 13. Its reflections over the diaphragm on this side. 14, 14. Left pleura costalis on the parietes of the chest. 15. Trachea. 16. Larynx. 17. Opening of the larynx and the epiglottic cartilage in situ. 18. Root and top of the tongue. 19, 19. Right and left bronchia. 20. The heart enclosed in pericardium. 21. Upper portion of diaphragm on which it rests. 22. Section of œsophagus. 23. Section of aorta. 24. Arteria innominata. 25. Primitive carotid arteries. 26. Subclavian arteries. 27. Internal jugular veins. 28. Second cervical vertebra. 29. Fourth lumbar.

is surrounded on every side by air. The lungs are two organs of considerable size, situate in the lateral parts of the chest, and subdivided into lobes and lobules, the shape and number of which cannot be readily determined. They are termed *right* and *left*, respectively, according to the side of the cavity of the chest which they occupy. The former consists of three lobes; the latter of two. Each of these exactly fills the corresponding cavity of the pleura; and they are separated from each other by a duplicature of the pleura—(the serous membrane that lines the chest, and is reflected over the lungs)—and by the heart. The colour of the lungs is generally of a marble blue; and the exterior is furrowed by figures of hexagonal shape. The appearance is not, however, the same at all ages, and under all circumstances. In infancy, they are of a pale red; in youth, of a darker colour; and in old age, of a livid blue.

The elements that compose them are;—the ramifications of the trachea; those of the pulmonary artery and pulmonary veins, besides the organic elements, that appertain to every living structure,—arteries, veins, lymphatics, nerves, and areolar tissue. The ramifications of the windpipe form the cavity of the organ of respiration. The trachea is continuous with the larynx, from which it receives the external air conveyed to it by the mouth and nose. It passes down to the thorax, at the anterior part of the neck, and bifurcates opposite the second dorsal vertebra, forming two large canals called *bronchi* or *bronchia*. One of these goes to each lung; and, after numerous subdi-

visions, becomes imperceptible; hence, the multitudinous speculations that have been indulged regarding the mode in which the bronchial ramifications terminate. Malpighi[1] believed, that they form vesicles, at the inner surface of which the pulmonary artery ramifies. Reisseisen[2] describes the vesicles as of a cylindrical, and somewhat rounded figure; and states, that they do not communicate with each other. Helvetius,[3] on the other hand, affirmed, that they end in cells, formed by the different constituent elements of the lung,—the cells having no determinate shape, or regular connexion with each other; whilst M. Magendie[4] asserts, that the minute bronchial division, which arrives at a lobe, does not enter it, but terminates suddenly as soon as it has reached the parenchyma; and, he remarks, that as the bronchus does not penetrate the spongy tissue of the lung, it is not probable, that the surface of the cells, with which the air comes in contact, is lined by a prolongation of the mucous coat, which forms the inner membrane of the air-passages. Mr. Hassall,[5] however, contrary to the opinion of most observers, and—as will be seen—to that of Mr. Rainey, one of the most recent of them, affirms, that in sections of recent lungs "it is a very easy matter not merely to determine the existence of epithelium in the air-cells, but also the fact of its cylinder and ciliated form and character," and this "fact" of the epithelium extending from the bronchial tubes into them—he adds—would seem in itself to imply that the mucous membrane also lines them.

Fig. 265.



A shaded Diagram, representing the Heart and Great Vessels, injected and in connexion with the Lungs: the Pericardium is removed.

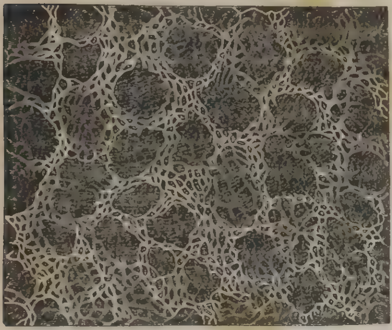
1. Right auricle. 2. Vena cava superior. 3. Vena cava inferior. 4. Right ventricle. 5. Pulmonary artery, dividing into two branches *a*, *a*, one for the right, the other for the left lung. 6. Point of the left auricle. 7. Part of left ventricle. 8. Aorta. 9, 10. Two lobes of the left lung. 11, 12, 13. Three lobes of the right lung. *a*, *a*. Right and left pulmonery arteries. *b*, *b*. Right and left bronchi. *v*, *v*. Right and left pulmonary veins. The relative position of these three vessels is seen to differ on the two sides.

The ramifications of the pulmonary artery are another constituent element of the lung. This vessel arises from the right ventricle of the heart, and, at a short distance from that organ, divides into two branches; one passing to each lung. Each branch accompanies the corresponding bronchus in all its divisions; and, at length, becomes capillary and imperceptible. Its termination, also, has given rise to conjecture. Malpighi conceived it to end at the mucous surface of the bronchi, in an

[1] Epist. de Pulmon., i. 133.
[2] Ueber den Bau der Lungen, u. s. w., Berlin, 1822; also, in Latin, Berl., 1822.
[3] Mémoires de l'Académ. pour 1718, p. 18.
[4] Précis, &c., ii. 309.
[5] The Microscopic Anatomy of the Human Body in Health and Disease, part xii. p. 381, London, 1848.

extremely delicate network, which he called *rete mirabile;* and this was, likewise, the opinion of Reisseisen. Bichat[1] admitted at the extremities of the pulmonary artery, and between that artery and the veins of the same name, vessels of a more delicate character, which he conceived to be the agents of hæmatosis, and called the *capillary system of the lungs.* This, however, is nothing more than the fine dense capillary network, formed by the distribution of the artery on the air-cells, from which the *pulmonary veins* arise. Their radicles communicate freely with those of the pulmonary artery. When we observe them distinctly, they are found uniting to constitute larger and larger veins, until they ultimately end in four large trunks, which open into the left auricle of the heart. The pulmonary arteries do not anastomose in their course; and according to Dr. Cammann,[2] the capillaries of one lobule do not communicate with those of another: the interstitial areolar membrane even of the most minute lobules was seen entirely free from colour when a coloured injection was thrown into the vessels.

Fig. 266.



Arrangement of the Capillaries of the Air-cells of the Human Lung.

In addition to these organic constituents, the lung, like other organs, receives arteries, veins, lymphatics, and nerves. It is not nourished by the blood of the pulmonary artery, which is not adapted for the purpose, seeing that it is venous. The *bronchial arteries* are its nutritive vessels. They arise from the aorta, and are distributed to the bronchi.

Around the bronchi, and near where they dip into the tissue of the lung, lymphatic glands—*bronchial glands*—exist, the colour of which is almost black, and with which the few lymphatic vessels, that arise from the superficial and deep-seated parts of the lung, communicate. Haller[3] has traced the efferent vessels of these glands into the thoracic duct.

The nerves, distributed to the lungs, proceed chiefly from the eighth pair or pneumogastric. A few filaments of the great sympathetic are also sent to them. The eighth pair—after having given off the superior laryngeal nerves, and some twigs to the heart—interlaces with numerous branches of the great sympathetic, and forms an extensive nervous network, called *anterior pulmonary plexus.* After this, the nerve gives off the recurrents, and interlaces a second time with branches of the great sympathetic, forming another network, called *posterior pulmonary plexus.* It then proceeds to the stomach, where it terminates. (See Figs. 198 and 225.) From these two plexuses the nerves proceed, that are distributed to the lungs. These accompany the bronchi, and

[1] Anatomie Générale, édit. de MM. Béclard, Blandin, and Magendie, ii. 381–386, Paris, 1832.
[2] New York Journal of Medicine, Jan., 1848.
[3] Elem. Physiologiæ, viii. 2, § 15, Lausann. 1764.

are spread chiefly on the mucous membrane of the air-tubes. The lung likewise receives some nerves directly from the three cervical ganglions of the great sympathetic, and from the first thoracic ganglion. In addition to these, a distinct system of nerves—the *respiratory system*, described in the first volume of this work (p. 89)—is supposed by Sir Charles Bell to be distributed to the multitude of muscles, that are associated in the respiratory function, in a voluntary or involuntary manner. This system includes one of the nerves just referred to—the eighth pair—and the phrenic nerves, which are distributed to the diaphragm. The various nerves composing it are intimately connected, so that, in forced or hurried respiration, in coughing, sneezing, &c., they are always associated in action. We have seen, however, that few physiologists now admit the respiratory system of Sir Charles.

Lastly; the lungs are constituted also of areolar tissue, which has been termed *interlobular tissue;* but it does not differ from areolar tissue in other parts of the body.

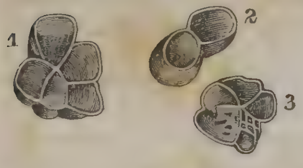
Such are the constituent elements of the pulmonary tissue; but, with regard to the mode in which they are combined to form the intimate texture of the lung we are not wholly instructed. We find, that the lobes are divided into lobules, and these, again, seem to be subdivided almost indefinitely, forming an extremely delicate spongy tissue, the areolæ of which can only be seen by the aid of the microscope.[1] It is generally thought, that the areolæ communicate with each other, and that they are enveloped by the areolar tissue which separates the lobules. M. Magendie[2] inflated a portion of lung, dried and cut it in slices, in order that he might examine the deep-seated cells. These appeared to him to be irregular, and to be formed by the final ramifications of the pulmonary artery, and the primary ramifications of the pulmonary veins; the cells of one lobule communicating with each other, but not with those of another lobule. Professor Horner,[3] of the University of Pennsylvania, has attempted to exhibit that this communication between the cells is lateral. After filling the pulmonary arteries and pulmonary veins with minute injection, the ramifications of the bronchi, with the air-cells, were distended to their natural size by an injection of melted tallow. The latter, being permitted to cool, the lung was cut into slices and dried. The slices were subsequently immersed in spirit of turpentine, and digested at a moderate heat for several days. By this process, all the tallow was removed, and the parts, on being dried, appeared to exhibit the air-cells empty, and, seemingly, of their natural size and shape. Preparations, thus made, appear to show the air-cells to be generally about the twelfth of a line in diameter, and of a spherical form, the cells of each lobule communicating freely, like the cells of fine sponge, by lateral apertures. The lobules, however, only communicate by branches of the bronchi, and not by contiguous cells. This would seem to negative the presumption of some anatomists and physiologists,—as Reisseisen, Blumenbach, Cuvier, &c.,—that each air-cell is insulated, communicating only with the minute bronchus that opens

[1] Hassall, op. cit.
[2] Précis, &c., ii. 309.
[3] American Journal of the Medical Sciences for Feb., 1832, p. 538, and op. cit.

into it; whilst it confirms the views of Haller, Monro (Secundus), Boyer, Sprengel, Magendie, Carpenter, and others;—but it is not easy to decide positively, where all is so minute. The observations of Dr. Addison[1] led him to maintain, that the views of Reisscisen and others are certainly true as regards the fœtal lung, in which the ultimate subdivisions of the bronchial tubes terminate in closed extremities. But when an animal has respired, the terminations are said to experience a great change. The membrane composing them offers but slight resistance to the pressure of the air, and is pushed forwards, and distended laterally into rounded inflations, forming a series of cells, which are moulded by mutual pressure into various angular forms, and which communicate freely with each other by large oval apertures. The passages, thus formed, do not communicate otherwise than by their connexion with the same bronchial tube, and the bloodvessels lie between the contiguous walls of each two of them, so that the blood in the capillaries is exposed to air on both sides. It would appear, also, from the researches of M. Bourgery,[2] that the developement of the air-cells,—and, consequently, the capacity for forcible inspiration,—continues in man to the age of thirty, at which time the capacity is greatest. Subsequently, it decreases, especially in those who suffer from cough,—the violence of the respiratory effort often causing rupture of the air-cells, and thus gradually producing the emphysematous state of the lungs so common in old people. After thirty, the capacity for forcible inspiration diminishes one-fifth in the first twenty years; one-fifth more in the next ten; and nearly one-half in the next twenty; and this gradual decrease of capacity for forcible inspiration is true of all persons, although one may have a greater general capacity of respiration than another of the same age. Hence the young person possesses a greater capacity of respiration, as it were, in reserve. The aged have little, and are, therefore, unfit for great exertion.

The observations of Mr. Rainey,[3] which have been adopted by many histologists, lead to the belief, that when the bronchia have attained the diameter of from $\frac{1}{50}$th to $\frac{1}{30}$th of an inch, they gradually lose their cylindrical form, and appear more like irregular passages—termed by Mr. Rainey *intercellular passages*—through the substance of the lung.

Fig. 267.



Air-cells from an Emphysematous Lung. (Leidy.)

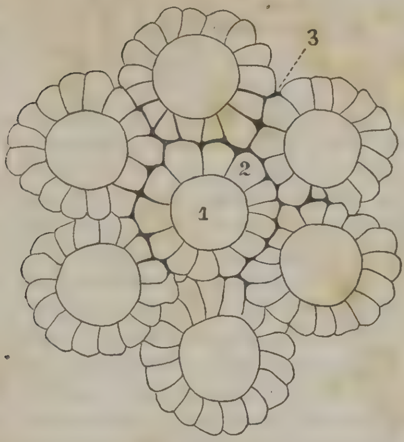
1. A group of air-cells laid open and exhibiting the fact that there is no lateral intercommunication. 2. Two air-cells; the one to the left exhibits its bronchiolar orifice. 3. Another group; to the left are represented two cells freely communicating from the partition being ruptured by over-distension; and between the two cells to the right are observed some inflated areolæ of areolar tissue.

These passages are clustered with air-cells, which have the appearance of polyhedral alveolar cavities separated by exceedingly thin septa, and do not open into one another by anastomosis or lateral communication,

[1] Proceedings of the Royal Society, March 17, 1842; and Philos. Transact. for 1842.
[2] Gazette Médicale, 16 Juillet, 1842, and Archives Générales de Méd., Mars, 1843.
[3] Medico-Chirurgical Transactions, vol. xxviii., London, 1845.

but communicate freely through the medium of the common air passage to which they belong. The marginal figure (Fig. 267) represents several groups of air-cells from an emphysematous lung, drawn the size of nature from a preparation by Dr. Goddard. The diagrams, Figs. 268 and 269,

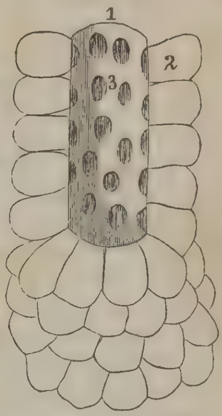
Fig. 268.



Transverse Section of a portion of the Pulmonary Parenchyma.

1. The orifices of bronchioles. 2. The air-cells arranged around the bronchioles, and opening into them, but not communicating laterally. 3. Interspaces filled with areolar tissue, which, when inflated, is liable to be mistaken for the true air-cells.

Fig. 269.



Longitudinal Section of the termination of a Bronchus.

1. The bronchiole, in which are seen the orifices (3) of the air-cells (2) arranged around it and at its termination.

are given by Dr. Leidy to facilitate the understanding of the relative arrangement of the air-cells to the minute bronchial tubes[1] in this view of the subject. Mr. Rainey affirms, as the result of actual observation, that the mucous lining of the bronchial tube is not continued along the intercellular passages and into the air-cells, a circumstance, which, as he suggests, explains the different effects of inflammation of the tubes and of the air-cells;—the latter, which are lined by fibro-areolar tissue, being accompanied by the exudation of fibrin instead of mucus. Anatomists, consequently, who, by the term "air-cell," meant simply the ultimate termination of a bronchial tube; and pathologists, who regarded bronchitis of the terminal extremities of those tubes and pneumonia as essentially alike, were nearer the truth than was generally admitted. It is proper to remark, that the researches of Mr. Rainey led him to conclude—in opposition to Dr. Addison,—that the fœtus, prior to the act of respiration, possesses fully formed air-cells, which are also surrounded by capillary plexuses.

The surface afforded by the air-cells is immense. Hales[2] supposed them to be polyhedral, and about one-hundredth part of an inch in diameter. The surface of the bronchi he estimated at 1635 square

[1] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit. by Dr. Leidy, ii. 119, Philad., 1849.

[2] Statical Essays, i. 242.

inches; and that of the air-cells at 40,000, making the surface of the whole lungs 41,635 square inches or 289 square feet,—equal to 19 times the surface of the body, which, at a medium, he computes to be 15 square feet. Keill[1] estimated the number of cells to be 1,744,186,015; and the surface 21,906 square inches; and Lieberkühn has valued it at the enormous amount of 1500 square feet.[2] M. Rochoux[3] estimates the number of cells at 600,000,000, and that there are about 17,790 grouped around each terminal bronchus. All that we can derive from these mathematical conjectures is, that the extent of surface is surprising, when we consider the small size of the lungs themselves.

Professor Horner[4] has published an account of various experiments, which exhibit the ready communication between the pulmonary air-vesicles and veins. By fixing a pipe into the human trachea, and permitting a column of water to pass gently, he found that the air-cells became distended with water; and that the left side of the heart filled, and the aorta discharged water freely from its cut branches. This experiment he repeated on human lungs on different occasions, and with like results. Very little water flowed from the pulmonary artery. In the sheep and the calf, however, when the experiment was practised upon them after they had been pretty thoroughly evacuated of blood, the water passed freely through both the pulmonary veins and the pulmonary arteries. Dr. Horner is disposed to infer, that his experiments exhibit a communication of the pulmonary air-vesicles by a direct route with the pulmonary bloodvessels, especially the veins; but this may well be questioned. It is possible, that such a communication may really have been made by the force of the column of water; and if not so, the passage of the fluid from air-cells to bloodvessels might have been effected through the pores, as in ordinary imbibition, which, we have elsewhere seen, is readily accomplished in the lungs, but not more readily perhaps than in the case of serous and other tissues under favourable circumstances. Hemorrhage by transudation occurs, we know, most rapidly at times through the coats of vessels; and a thinner fluid would of course transude more easily. It can scarcely be doubted, from Dr. Horner's experiments, that a certain arrangement exists between the air-vesicles and the pulmonary veins in man, which allows a more ready imbibition and transudation; but what that arrangement is admits of question.

Each lung is covered by the *pleura*,—a serous membrane analogous to the peritoneum,—and, in birds, a prolongation of the latter. This membrane is reflected from the adjacent surface of the lung to the pericardium which covers the heart, and is then spread over the interior paries of the half of the thorax to which it belongs; lining the ribs and intercostal muscles, and covering the convex or upper surface of the diaphragm. There are, consequently, two pleuræ, each of which is confined to its own half of the thorax, lining its cavity and covering

[1] Tentam. Med. Phys., p. 80.

[2] Blumenbach, in Elliotson's Physiology, p. 197, Lond., 1835.

[3] Gazette Médicale, 4 Janv., 1845.

[4] Amer. Journ. of the Medical Sciences, April, 1843, p. 332; and Special Anatomy and Histology, 6th edit., ii. 163.

the lung. Behind the sternum, however, they are contiguous to each other, and form the partition called *mediastinum*, which extends between the sternum and spine. Fig. 270 exhibits the boundaries of the two cavities of the pleura. The middle space between is the mediastinum. Within this septum, the heart, enveloped by the pericardium, is situate, and separates the pleuræ considerably from each other. Anatomists generally subdivide the mediastinum into two regions; one passing from the front of the pericardium to the sternum, called *anterior mediastinum;* the other, from the posterior surface of the pericardium to the dorsal vertebræ,—*posterior mediastinum;* and, by some, the part which is within the circuit of the first ribs, is termed *superior mediastinum.* The second of these contains the most important organs,—the lower end of the trachea, œsophagus, aorta, vena azygos, thoracic duct, and pneumogastric nerves. The portion of the pleura covering each lung, is called *pleura pulmonalis;* that which lines the thorax, *pleura costalis.* It is obvious that, as in the case of the abdomen, the viscera are not in the cavity of the pleura, but external to it; and that there is no communication between the serous sac of one side and that of the other.

Fig. 270.

Outline of a Transverse Section of the Chest, showing the relative position of the Pleuræ to the Thorax and its Contents.

1. Skin on the front of the chest drawn up by a hook. 2. Skin on the sides of the chest. 3. That on the back. 4. Subcutaneous fat and muscles on the outside of the thorax. 5. Section of the muscles in the vertebral gutter. 6. Section of fifth dorsal vertebra. 7. Spinal canal. 8. Spinous process. 9, 9, 10, 10. Sections of ribs and intercostal muscles. 11. Their cartilages. 12. Sternum. 13. Division of the pulmonary artery. 14. Exterior surface of lungs. 15. Posterior face of lungs. 16. Anterior face of lungs. 17. Inner face of lungs. 18. Anterior face of heart covered by pericardium. 19. Pulmonary artery. 20, 21. Its division into right and left branches. 22. Portion of right auricle. 23. Descending cava cut off at right auricle. 24. Section of left bronchus. 25. Section of right bronchus. 26. Section of œsophagus. 27. Section of thoracic aorta. The space between figures 12 and 18 and the two 16s is the anterior mediastinum, and the space which contains 26 and 27 is the posterior mediastinum. These spaces are formed by the reflections of the pleuræ.

The use of the pleura is to attach the lungs by their roots to their respective cavities, and to facilitate their movements. To aid this, the membrane is always lubricated by a fluid, exhaled from its surface. The other surface is attached to the lung in such a manner, that air cannot get between it and the parietes of the thorax. Dr. Stokes[1] admits a proper fibrous tunic of the lungs. In a healthy state, this capsule, although possessing great strength, is transparent, a circumstance in which it differs from the fibrous capsule of the pericardium, and which, Dr. Stokes thinks, has probably led to its being overlooked. It invests the whole of both lungs; covers a por-

[1] On Diseases of the Chest, Part i. p. 460, Dublin, 1837; or Dunglison's American Medical Library edition, p. 301, Philad., 1837.

tion of the great vessels; and the pericardium seems to be but its continuation,—endowed, in that particular situation, with a greater degree of strength, for purposes that are obvious. It covers the diaphragm where it is more opaque: in connexion with the pleura, it lines the ribs; and, turning, forms the mediastina, which are thus shown to consist of four layers,—two serous and two fibrous. It seems, that Dr. Hart, of Dublin, had, for years, demonstrated this tunic to his class.

It was, at one time, the prevalent belief, that air always exists in the cavity of the chest. Galen supported the opinion by the fact, that, having applied a bladder, filled with air, to a wound, which had penetrated the chest, the air was drawn out of the bladder at the time of inspiration. This was also maintained by Hamberger, Hales,[1] and numerous others. The case, alluded to by Galen, is insufficient to establish the position, inasmuch as we have no evidence, that the wound did not also implicate the pulmonary tissue. Since the time of Haller, who opposed the prevalent doctrine by observation and reasoning, the fact of the absence of air in the cavity of the pleura has been generally considered established. It is obvious, that its presence there would materially interfere with the dilatation of the lungs, and thus be productive of fatal consequences; besides, anatomy instructs us, that the lungs lie in pretty close contact with the pleura costalis. When the intercostal muscles are dissected off, and the pleura costalis is exposed, the surface of the lungs is seen in contact with that transparent membrane; and when the pleura is punctured, the air rushes in, and the lungs retire, in proportion as the air is admitted. This occurs in cases of injuries inflicted upon the chest of the living animal. Moreover, if a dead or living body be placed under water, and the pleura be punctured, so as not to implicate the lungs, it has been found by the experiments of Brunn, Sprögel, Caldani, Sir John Floyer, Haller,[2] and others, that not a bubble of air escapes,—which would necessarily be the case, if air were in the cavity of the pleura.

2. ATMOSPHERIC AIR.

The globe is surrounded everywhere, to the height of fifteen or sixteen leagues, by a rare and transparent fluid called *air;* the total mass of which constitutes the *atmosphere.* Atmospheric air, although invisible, can be proved to possess the ordinary properties of matter; and, amongst these, weight. It also partakes of the character of a fluid, adapting itself to the form of the vessel in which it is contained, and pressing equally in all directions.

As air is possessed of weight, it results, that every body on the earth's surface must be subjected to its pressure; and as it is elastic or capable of yielding to pressure, the part of the atmosphere near the surface must be denser than that above it. As a body, therefore, ascends, the pressure will be diminished; and this accounts for the different feelings experienced by those who ascend lofty mountains, or voyage in balloons, into the higher strata of the atmosphere. M. Ed-

[1] Statical Essays, ii. 81.
[2] Element. Physiol., viii. 2, § 3, Lausann., 1764.

wards[1] ascribes part, at least, of the effect produced upon the breathing, at great elevations, to the increased evaporation which takes place from the skin and lungs; and in many aerial voyages great inconvenience has certainly been sustained from this cause.

The pressure of the atmosphere at the level of the sea is the result of the whole weight of the atmosphere, and is capable of sustaining a column of water thirty-four feet high, or one of mercury of the height of thirty inches, as in the common *barometer*. This is equal to about fifteen pounds avoirdupois on every square inch of surface; so that the body of a man of ordinary stature, the surface of which Haller estimates to be fifteen square feet, sustains a pressure of 32,400 pounds. Yet, as the elasticity of the air within the body exactly balances or counteracts the pressure from without, he is not sensible of it.

The experiments of Davy, Dalton, Gay Lussac, Humboldt, Despretz, and others, have shown, that pure atmospheric air is composed essentially of two gases, *oxygen* and *nitrogen* or *azote*, which exist in it in the proportion of 21 of the former to 79 of the latter: according to MM. Dumas and Boussingault,[2] 20·81 of the former to 79·19 of the latter: Dr. T. Thomson says 20 of oxygen to 80 of nitrogen; and these proportions have generally been found to prevail in the air whencesoever taken;—whether from the summit of Mont Blanc, the top of Chimborazo, the sandy plains of Egypt, or from an altitude of 23,000 feet in the air.[3] It has been affirmed, indeed, that the proportion of the gases is subject to a variation of two or three parts in the thousand, in situations where the oxygen is much exposed to absorption, as over the sea, when there is no wind.[4] Chemical analysis has not been able to detect the presence of any emanation from the soil of the most insalubrious regions, or from the bodies of those labouring under the most contagious diseases,—malignant and *material* as such emanations unquestionably must be. The great uniformity in the proportion of the oxygen to the nitrogen in the atmosphere has led to the conclusion, that as there are many processes, which consume the oxygen, there must be some natural agency, by which a quantity of oxygen is produced equal to that consumed. The only source, however, by which oxygen is known to be supplied, is the process of vegetation. A healthy plant absorbs carbonic acid during the day; appropriates the carbon to its own necessities, and gives off the oxygen with which it was combined. This is a nutritive or digestive process; but at the same time the plant is respiring, or consuming oxygen, and giving off carbonic acid. In bright light, however, the former function is so active as to preponderate over, and mask the latter. During the night an opposite effect is produced. Digestion is almost suspended; and respiration is preponderant. Oxygen is then taken from the air, and carbonic acid given off; but the experiments of Davy and Priestley show, that plants, during

[1] De l'Influence des Agens Physiques, &c., p. 493, Paris, 1824.

[2] Annales de Chimie et de Physique, iii. 257, Paris, 1841.

[3] Art. Atmosphere, (Physical and Chemical History.) by Dr. R. M. Patterson, in Amer. Cyclopedia of Practical Medicine and Surgery, vol. ii. p. 526, Philad., 1836.

[4] Lewy, Comptes Rendus, 1842; also, Morren, Annales de Chimie et de Physique, xii. 5, Paris, 1844.

the twenty-four hours, yield more oxygen than they consume. It seems impossible, however, to look to this as the great cause of equilibrium between the oxygen and the nitrogen. Its influence can extend to a small distance only; yet the uniformity has been found to prevail, as we have seen, in the most elevated regions, and in countries whose arid sands never admit of vegetation.

In addition to the oxygen and nitrogen,—the principal constituents of atmospheric air,—another gas exists in very small proportion, but is always present. This is *carbonic acid*. It was found by De Saussure on Mont Blanc, and by Humboldt in air brought down by Garnerin, the aeronaut, from the height of several thousand feet. The proportion is estimated by Dalton not to exceed the $\frac{1}{1000}$th or $\frac{1}{1400}$th of its bulk. In one of the wards of La Pitié, in Paris, which had been kept shut during the night, M. Felix Leblanc[1] found a larger portion of carbonic acid, nearly $\frac{3}{1000}$ths; and in a dormitory of La Salpétrière, the air yielded $\frac{8}{1000}$ths; the largest proportion found by him in hospitals. In the lecture room of the Sorbonne, which is capable of containing 1000 cubic inches of air, after a lecture an hour and a half long, and at which 900 persons were present, the oxygen was found to have lost 1 in every hundred, although two doors were open; whilst the carbonic acid was increased in rather a greater ratio. In a ward in an institution for children, although the door was half open, and there was an open space in the roof, the air was found to contain $\frac{3}{1000}$ths of carbonic acid, and there was a proportional diminution of oxygen. Dr. Dalton analyzed the air of a room in which 50 candles had been kept burning, and 500 people had been collected for two hours, and found it to contain one per cent. of carbonic acid.[2] M. Boussingault[3] has made 142 analyses of large quantities of the air of Paris, whence he has drawn the generally admitted conclusion, that the quantity of carbonic acid contained in the air of large towns is not above the average. The average quantity found by him was 3·97 volumes in 10,000. Although largely produced where combustion is extensively going on, and where numbers of persons are congregated together, as in large cities, it becomes so speedily diffused in the atmosphere as not to excite any marked difference between the air in them and in rural dstricts.[4]

These, then, may be looked upon as the constituents of atmospheric air. There are certain substances, however, which are adventitiously present in variable proportions; and which, with the constitution of the atmosphere as to density and temperature, are the causes of general or local solubrity, or the contrary. Water is one of these. The quantity, according to M. de Saussure, in a cubic foot of air, charged with moisture, at 65° Fahr., is 11 grains. Its amount in the atmosphere is very variable, owing to the continual change of temperature to which the air is subject; and even when the temperature is the same,

[1] Gazette Méd. de Paris, 11 Juin, 1842.
[2] London and Edinb. Philos. Magazine, xii. 405, 1838.
[3] Annales de Chimie et de Physique, Mars, 1844. See, also, M. Lewy, loc. cit.
[4] See Dr. John Reid, article Respiration, in Cyclopædia of Anat. and Physiol., Pt. xxxii. p. 326, London, April, 1848.

the quantity of vapour is found to vary, as the air is rarely in a state of saturation. The varying condition as to moisture is indicated by the *hygrometer*. From a comparison of numerous observations, Gay Lussac affirms, that the mean hygrometric state of the atmosphere is such, that the air holds just one-half the moisture necessary for its saturation. In his celebrated aerial voyage, he found it to contain but one-eighth. This is, perhaps, the greatest degree of dryness ever noticed.

It has been presumed, that the hygrometric condition of the air has more agency in the production of disease than either the barometric or thermometric. It is not easy to say, which exerts the greatest influence: probably all are concerned; and when we have a union of particular barometric, thermometric, hygrometric, electric, and other conditions, we have certain epidemics existing, which do not prevail under any other combination. When the air is dry, we feel a degree of elasticity and buoyancy; whilst, if it be saturated with moisture,—especially during the heat of summer,—languor, lassitude, and indisposition to mental or corporeal exertion are experienced.

In addition to aqueous vapour, numerous emanations from animal and vegetable substances are generally present, especially in the lower strata of the atmosphere; by which the salubrity of the air may be more or less affected. All living bodies, when crowded together, deteriorate the air so much as to render it unfit for the maintenance of the healthy function. If animals be kept crowded together in ill-ventilated apartments, they speedily sicken. The horse becomes attacked with *glanders;* fowls with *pep*, and sheep with a disease peculiar to them if they be too closely folded. This is probably a principal cause of the insalubrity of cities compared with the country. In them, the air must necessarily be deteriorated by the impracticability of due ventilation; and this, with the want of due exercise, is a fruitful cause of cachexia—and of tuberculous cachexia; hence, also, it is, that in work-houses and manufactories, diseases dependent on this condition of constitution are prevalent. One of the greatest evidences we possess of the positive insalubrity of towns is in the case of the young. In London, the proportion of those that die annually under five years of age to the whole number of deaths is as much as thirty-eight per cent., and under two years, twenty-eight per cent.; in Paris, under two years of age twenty-five per cent.; and in Philadelphia and Baltimore, rather less than a third. These estimates may be considered approximations; the proportions varying somewhat, according to the precise year in which they have been taken. Manifest, however, as is the existence of some deleterious principle, in these cases, it has always escaped the researches of the chemist.

Lastly. Air is indispensable to organic existence. No being—animal or vegetable,—can continue to live without a due supply of it; nor can any other gas be substituted for it. This is proved by the fact, that all organized bodies cease to exist, if placed *in vacuo*. They require, likewise, renovation of the air, otherwise they die; and if the residual air be examined, it is found diminished in quantity, and to have received a gas, which is totally unfit for life,—*carbonic acid*. The experiments of Hales prove this as regards vegetables; whilst Spallan-

zani and Vauquelin have confirmed it in the case of the lower animals. The necessity for the presence of air, and its due renewal,—as regards man and the upper classes of animals,—is sufficiently obvious. Not less necessary is a due supply of it to aquatic animals. They can be readily drowned, when the air in the water is consumed, if prevented from coming to the surface. If the fluid be put under the receiver of an air-pump, and the air be withdrawn, or if the vessel be placed so that the air cannot be renewed, the same changes are found to have been produced in it. Hence the necessity for making holes through the ice, where small fish-ponds are frozen over, if we are desirous of preserving the fish alive. The necessity for the renewal of air is not, however, alike imperative in all animals. Whilst the mammalia, birds, fishes, &c., speedily expire, when placed under the receiver of an air-pump, if the receiver be exhausted; the frog is but slightly incommoded. It swells up almost to bursting, but retains its position, and when the air is admitted seems to have sustained no injury. The exception, afforded by the amphibious animal to the ordinary effects of destructive agents, we have already had occasion to refer to more than once; and it is exemplified in the fact, now indisputable, that the toad has been found alive in the substance of trees and rocks, where no access of air appeared practicable.

The influence of air on mankind is interesting and important in its hygienic relations, and has accordingly been a topic of study since the days of Hippocrates. In other works, it has been investigated, at considerable length, by the author.[1]

3. PHYSIOLOGY OF RESPIRATION.

a. *Mechanical Phenomena of Respiration.*—Within certain limits, the function of respiration is under the influence of volition. The muscles, belonging to it, have consequently been termed *mixed*, as we can at pleasure increase or diminish their action, but cannot arrest it altogether, or for any great length of time. If, by a forced inspiration, we take air into the chest in large quantity, we find it impossible to keep the chest in this condition beyond a certain period. Expiration irresistibly succeeds, and the chest resumes its pristine situation. The same occurs if we expel the air as much as possible from the lungs. The expiratory effort cannot be prolonged indefinitely, and the chest expands in spite of the effort of the will. The most expert divers do not appear capable of suspending the respiratory movements longer than 95 or 100 seconds. Dr. Lefèvre[2] found the average period of the Turkish divers to be 76 seconds for each man. These facts have given rise to two curious and deeply interesting topics of inquiry;—the cause of the first inspiration in the new-born infant; and of the regular alternation of inspiration and expiration during the remainder of existence? The first of these will fall under consideration when we investigate the physiology of infancy; the latter will claim some atten-

[1] Human Health, Philad., 1844; and American Cyclopædia of Practical Medicine and Surgery, art. Atmosphere, p. 527, Philad., 1836.

[2] Loudon's Magazine of Nat. Hist., p. 617, Dec, 1836; and Dunglison's Amer. Med. Intelligencer, p. 30, April 15, 1837.

tion at present. Haller[1] attempted to account for the phenomenon by the passage of the blood through the lungs being impeded during expiration,—a reflux of blood into the veins, and a degree of pressure upon the brain, being thus induced; hence a painful sensation of suffocation in consequence of which the muscles of inspiration are called into action by the will, for the purpose of enlarging the chest, and, in this way, removing the impediment. The same uneasy feelings, however, ensue from inspiration, if too long protracted: the muscles cease to act, and, by their relaxation, the opposite state of the chest is induced. Whytt[2] conceived, that the passage of the blood through the pulmonary vessels is impeded by expiration, and a sense of anxiety is thus produced. The unpleasant sensation acts as a stimulus upon the nerves of the lungs and the parts connected with them, which arouses the energy of the sentient principle; and this, by acting in a reflex manner, causes contraction of the diaphragm, enlarges the chest, and removes the painful feeling. The muscles then cease to act, in consequence of the stimulus no longer existing. These, and all other methods of accounting for the phenomena, are, however, too pathological. From the first moment of respiration the process appears to be accomplished without the slightest difficulty, and to be as much a part of the instinctive extra-uterine actions of the frame, as circulation, digestion, or absorption. It is obviously an internal sensation, after respiration has been once established; and, like all internal sensations, is inexplicable in our existing state of knowledge. The part which developes the impression is probably the lung, through its ganglionic nerves; and the pneumogastric nerves convey the impression to the brain or spinal marrow, which calls into action the muscles of inspiration. We say, that the action of impression arises in the lungs, and this, from some internal cause, connected with the office to be filled in the economy: but in so saying we sufficiently exhibit our total want of acquaintance with its nature.

The movements of inspiration and expiration, which, together, constitute the function of respiration, are entirely accomplished by the dilatation and contraction of the thorax. Air enters the chest when the latter is expanded; and is driven out when the chest is restored to its ordinary dimensions;—the thorax thus seeming to act like an ordinary pair of bellows with the valve stopped: when the sides are separated, the air enters at the nozzle, and when they are brought together, it is forced out.

(1.) INSPIRATION.

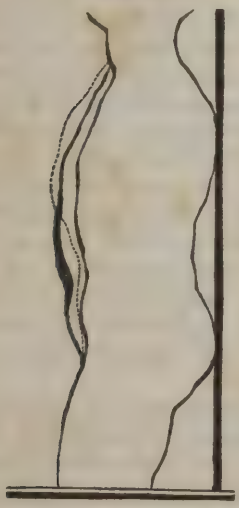
The augmentation of the capacity of the thorax, which constitutes inspiration, may be effected to a greater or less extent, according to the number of muscles that are thrown into action. The chest may, for example, be dilated by the diaphragm alone. This muscle, as we have seen, in its ordinary relaxed condition, is convex towards the chest. When, however, it contracts, it becomes more horizontal; in

[1] Elementa Physiologiæ, viii. 4, 17, Lausann., 1764.

[2] An Essay on the Vital and other Involuntary Motions of Animals, sect. viii., Edinb., 1751.

this manner augmenting the cavity of the chest in a vertical direction. The sides or lateral portions of the diaphragm, which are fleshy and correspond to the lungs, descend more, in this movement, than the central, tendinous portion, which is moreover kept immovable by its attachment to the sternum, and its union with the pericardium. In the gentlest of all breathing, the diaphragm appears to be the sole agent of inspiration; and in cases of inflammation of the pleura costalis, or of fractured rib, our endeavours are directed to the prevention of any elevation of the ribs by which the diseased part might be put upon the stretch. Generally, however, as the diaphragm descends, the viscera of the abdomen are compressed; the abdominal muscles relaxed; the abdomen is rendered more prominent, and the ribs and the breast bone are raised so that the latter is protruded. When the diaphragm acts, and, in addition, the ribs and sternum are raised, the cavity of the chest is still farther augmented.

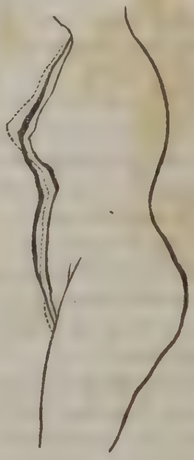
Fig. 271.



The Changes of the Thoracic and Abdominal Walls of the Male during Respiration.

The back is supposed to be fixed in order to throw forward the respiratory movement as much as possible. The outer black continuous line in front represents the ordinary breathing movement: the anterior margin of it being the boundary of *inspiration*, the posterior margin the limit of *expiration*. The line is thicker over the abdomen, since the ordinary respiratory movement is chiefly abdominal: thin over the chest, for there is less movement over that region. The dotted line indicates the movement on deep inspiration, during which the sternum advances while the abdomen recedes.

Fig. 272.



The Respiratory Movements in the Female.

The lines indicate the same changes as in the last figure. The thickness of the continuous line over the sternum shows the larger extent of the ordinary breathing movement over that region in the female than in the male.

In young children inspiration is effected almost wholly by the diaphragm; and as in diaphragmatic breathing the movement of the

parietes of the abdomen is more marked than that of any other part, this has been termed the *abdominal mode* or *type* of respiration.

In adult men, the lower part of the chest and sternum move more largely than in women; who, owing to greater mobility of the first rib, have a more extensive movement of the upper than of the lower part of the chest,—an arrangement which, it has been suggested, may have for its object the providing of sufficient space for respiration when the lower part of the chest is encroached upon by the pregnant uterus. The former is called by MM. Beau and Maissiat the *costo-inferior* or *inferior costal;* the latter the *costo-superior* or *superior costal* type of respiration.[1]

From the admeasurements of Mr. Sibson[2] it appears, that in health the inspiratory movement of the walls of the chest, during tranquil breathing, is only from two to six-hundredths of an inch; whilst that of the abdomen is about three-tenths of an inch. During a deep inspiration, the expansive motion of the walls of the chest is, in front, about one inch; and at the sides about two-thirds of an inch; and that of the abdomen about one inch. The expansion of the two sides of the chest is nearly equal; the left side does not, however, expand quite so much as the right over the lower two-thirds, owing to the position of the heart.

The mechanism, by which the ribs are elevated, has been productive of more controversy than the subject merits. Haller[3] asserted, that the first rib is immovable, or at least admits of but trifling motion when compared with the others; and he denied that the thorax, as a whole, makes any movement of either elevation or depression; affirming that the ribs are raised successively towards the top of the cavity; and this to a greater extent as they are more distant from the first. M. Magendie,[4] on the other hand, denies that they are elevated in this manner; and endeavours to show that they are all raised at the same time; that the first rib, instead of being the least movable, is the most so; and that the disadvantage, which the lower ribs possess in the movement, by their admitting of less motion in their posterior articulations, is compensated by the greater length of those ribs. This compensation he considers to have its advantages; for as the true ribs, with their cartilages and the sternum, usually move together, and the motion of one of these parts almost always induces that of the rest, it would follow, that if the lower ribs were more movable, they could not execute a more extensive movement than they do; whilst the solidity of the thorax would be diminished.

By the elevation, then, of the ribs, and the depression of the diaphragm, the chest is augmented, and a deeper inspiration effected than when the diaphragm acts singly. In this elevation of the ribs, we see the advantage of their obliquity as regards the spine. Had they been horizontal, or inclined obliquely upwards, any elevation would neces-

[1] Archives Générales de Médecine, iii. 263, Paris, 1843; also, Kirkes and Paget, Manual of Physiology, Amer. edit., p. 127, Philad., 1849.
[2] Provincial Medical and Surgical Journal, Sept. 5, 1849.
[3] Elementa Physiologiæ, viii. 4, Lausann., 1764.
[4] Précis, &c., 2de édit., ii. 316.

sarily have contracted the thoracic cavity, and thus favoured expiration instead of inspiration.

The muscles chiefly concerned in inspiration are the intercostals, and those that arise, either directly or indirectly from the spine, head, or upper extremities, and that can, in any manner, elevate the thorax. Amongst these are the scaleni antici and postici, levatores costarum, the muscles of the neck, which are attached to the sternum, &c. The elasticity of the cartilages, and the weight of the osseous portions of the parietes of the chest, must afford considerable resistance to the action of the inspiratory muscles in dilating it. It is probable, however, that the estimates of Dr. Hutchinson[1] are far above the reality. He calculates, that the force which the muscles of inspiration have to overcome in ordinary breathing from these sources is probably at least equal to about 100 lbs.; and in deep inspiration to about 300 lbs.; and yet, in these calculations, the additional resistance from the elasticity of the lungs is not taken into the account.

As no air exists in the cavity of the pleura, it necessarily happens, that when the capacity of the chest is augmented, the residuary air, contained in the air-cells of the lungs after expiration, is rarefied; and, in consequence, the denser air without enters the larynx by the mouth and nose, until the air within the lungs has attained the density, which the residuary air had, prior to inspiration,—not that of the external air, as has been affirmed.[2] At the time of inspiration, the glottis opens by the relaxation of the arytenoidei muscles, as M. Legallois[3] proved by experiments performed at the *Ecole de Médecine* of Paris. On exposing the glottis of a living animal, the aperture is found to dilate distinctly at each inspiration, and contract at each expiration. If, according to M. Magendie, the eighth pair of nerves be divided low down in the neck, and the dilator muscles of the glottis, which receive their nerves from the recurrents—branches of the eighth pair—be thus paralysed, the aperture is no longer enlarged during inspiration, whilst the constrictors—the arytenoidei muscles, which receive their nerves from the superior laryngeal,—given off above the point of section, preserve their action, and close the glottis more or less completely.

When air is inspired through the mouth, the velum is raised, so as to allow it to pass freely to the glottis; and, in forced inspiration, it is so horizontal as to completely expose the pharynx to view. The physician takes advantage of this in examining morbid affections of those parts, and can often succeed much better in this way than by pressing down the tongue. On the other hand, when inspiration is effected entirely through the nose, the velum palati is depressed until it becomes vertical, and there are no obstacles to the free entrance of the air into the larynx. In such case, where difficulty of breathing exists, the small muscles of the alæ nasi are frequently thrown into violent action, alternately dilating and contracting the apertures of the nostrils: hence this is a common symptom in pulmonary affections.

[1] Medico-Chirurgical Transactions, xxix. 205, London, 1846.
[2] Animal Physiology, Library of Useful Knowledge, p. 100, Lond., 1829.
[3] Œuvres, p. 177, Paris, 1824.

Mayow[1] conceived, that air enters the lungs in inspiration as it would a bladder put into a pair of bellows, and communicating with the external air by the pipe of the instrument. The lungs, however, are not probably so passive as this view would indicate. In cases of pulmonary hernia, the extruded portion has been observed to dilate and contract in inspiration and expiration. Reisseisen believed this to be owing to muscular fibres, which Meckel and himself conceived to make the whole circuit of the bronchial ramifications. They are not, however, generally admitted by anatomists; and the phenomenon is usually ascribed to the bronchi having in their composition the highly elastic tissue, which is an important constituent of arteries. Laennec[2] affirms, that he has endeavoured, without success, to verify the observations of Reisseisen; but that the manifest existence of circular fibres in branches of a moderate size, and the phenomena presented by many kinds of asthma, induce him to consider the temporary constriction and occlusion of the minute bronchial ramifications as a thing established. The muscular action of the lungs may, indeed, be demonstrated by galvanizing them shortly after they have been taken from the body; when they contract so as to lift up water placed in a tube introduced into the trachea;[3] and it is affirmed by M. Longet[4] and by Volkmann,[5] that they may be made to contract by stimulating their nerves. The latter physiologist tied a glass tube, drawn fine at one end, into the trachea of a decapitated animal; and when the small end was turned to the flame of a candle, he galvanized the trunk of the pneumogastric nerve. On each application, the flame was blown upon; and once it was extinguished.

In the trachea, an obvious muscular structure exists in the posterior third, where the cartilages are wanting. There it consists of a thin muscular plane, the fibres of which pass transversely between the interrupted extremities of the cartilaginous rings of the trachea and bronchi, to which a layer of longitudinal fibres may at times be seen superadded.[6] The use of the transverse muscular tissue, as suggested by Dr. Physick,[7] and after him by M. Cruveilhier and Sir Charles Bell,[8] is to diminish the calibre of the air-tubes in expectoration; so that the air having to pass through the contracted portion with greater velocity, its momentum may remove the secretions that are adherent to the mucous membrane. The explanation is ingenious and probably just.

M. Magendie[9] asserts, that the lung has a constant tendency to return upon itself, and to occupy a smaller space than it fills; and that it consequently exerts a degree of traction on every part of the parietes of the thorax. This traction has but little effect upon the ribs, which cannot

[1] Tractatus Quinque, p. 271, Oxon., 1674.

[2] On the Diseases of the Chest, &c., 4th edit., Lond., 1834: reprinted in this country, Philad., 1835.

[3] C. J. B. Williams, Report of the Meeting of the British Association, in Athenæum for 1840, p. 802.

[4] Traité de Physiologie, ii. 328, Paris, 1850.

[5] Art. Nervenphysiologie, in Wagner's Handwörterbuch der Physiologie, 10te Lieferung, s. 586, Braunschweig, 1845.

[6] Goddard, in Wilson's Anatomist's Vade-Mecum, Amer. edit., p. 404, note, Philad., 1843.

[7] Horner's Lessons in Practical Anat., p. 179, Philad., 1836.

[8] Philos. Transact. for 1832, p. 301.

[9] Précis, &c., ii. 325.

yield; but upon the diaphragm it is considerable. It is, in his opinion, the cause why that muscle is always tense, and drawn so as to be vaulted upwards; when the muscle is depressed during contraction, it is compelled to draw down the lungs towards the base of the chest, so that they are stretched, and by virtue of their elasticity have a powerful tendency to return upon themselves, and draw the diaphragm upwards. If a puncture be made into the chest in one of the intercostal spaces, the air will enter the chest through the aperture, and the lung will shrink. By this experiment, the atmospheric pressure is equalized on both surfaces of the lung, and the organ assumes a bulk determined by its elasticity and weight. Owing to this resiliency of the lungs, and to their consequent tendency to recede from the pleura costalis, there is less pressure upon all the parts against which the lungs are applied; and, accordingly, the heart is not exposed to the same degree of pressure as the parts external to the chest; and the degree of pressure is still farther reduced, when the chest is fully dilated, the lungs farther expanded, and their elastic resiliency increased. Dr. Carson[1] states, that in his experiments on calves, sheep, and large dogs, the resiliency of the lungs was found to be balanced by a column of water, varying in height from a foot to a foot and a half; and in rabbits and cats by a column varying in height from six to ten inches.

Many physiologists have pointed out three degrees of inspiration, but it is manifest that there may be innumerable shades between them:—1. *Ordinary gentle inspiration*, owing simply to the action of the diaphragm; or, in addition, to a slight elevation of the chest. 2. *Deep inspiration*, when, with the depression or contraction of the diaphragm, there is evident elevation of the thorax; and, lastly, *forced inspiration*, when the air is strongly drawn in by the rapid dilatation produced by the action of all the respiratory muscles that elevate the chest directly or indirectly.

Trials have been instituted for determining the quantity of air taken into the lungs at an inspiration; and considerable diversity, as might be expected, exists in the evaluations of different experimenters.[2] We have just remarked, that, in the same individual, the inspiration may be gentle, deep, or forced; and, in each case, the quantity of air inspired will necessarily differ. There is, likewise, considerable diversity in individuals; so that an approximation can alone be attained. The following table sufficiently exhibits the discordance on this point. Many, however, of the estimates, which seem so discrepant, may probably be referred to imperfection in the mode of conducting the experiment, as well as to the causes above mentioned:—

[1] Philosophical Transactions, for 1820, p. 42.

[2] Dr. Marshall Hall has devised a *pneumatometer* for this purpose. See art. Irritability, in Cyclop. of Anat. and Physiol., July, 1840.

	Cubic inches at each Inspiration.		Cubic inches at each Inspiration.
Reil, ...	42 to 100	Dalton, ...	30
Menzies, Sauvages, Hales, Haller, Ellis, Sprengel, Sömmering, Thomson, Bostock, . .	40	Jeffreys, ...	26
		Herbst, ...	24 to 30
		Herholdt, ...	20 to 29
		Jurine and Coathupe,	20
		Allen and Pepys, . .	16½
		T. Thomson, . . .	16
		J. Borelli, ...	15 to 40
		Goodwin, ...	14
		Sir H. Davy, . . .	13 to 17
Jurin, ...	35 to 38	Abernethy and Mojon,	12
Fontana, ...	35	Keutsch, ...	6 to 12
Richerand, ...	30 to 40		

In passing through the mouth, nasal fossæ, pharynx, larynx, trachea, and bronchi, the inspired air acquires nearly the temperature of the body; and, if it be cool, the same quantity by weight occupies a much larger space in the lungs, owing to its rarefaction in those organs. According to Valentin, the temperature of the expired air is 99°·5 Fahr., when breathing an atmosphere of moderate temperature. In its passage, too, it becomes mixed with the halitus, that is constantly exhaled from the mucous membrane of the air-passages: in this condition, it enters the air-cells, and becomes mixed, by diffusion, with the residuary air.

It is obvious, that if we knew the exact capacity of the lungs in an individual in health, we might be able to determine the extent of solidification in pulmonary affections by the diminution in their capacity. Owing, however, to our want of this requisite preliminary knowledge, the test is not of much avail.

(2.) EXPIRATION.

An interval, scarcely appreciable, elapses after the accomplishment of inspiration, before the reverse movements of expiration succeeds; and the air is expelled from the chest. The great cause of this expulsion is the restoration of the chest to its former dimensions; and the elasticity of the yellow tissue composing the bronchial ramifications, which has been put upon the stretch by the air rushing into them during inspiration. The restoration of the chest to its dimensions may be effected simply by the cessation of the contraction of the muscles, that have raised it, and the elasticity of the cartilages, that connect the bony portions of the ribs with the sternum or breast-bone. In active expiration, however, the ribs are depressed by the contraction of appropriate muscles, and the chest is still farther contracted. The chief expiratory muscles are the triangularis sterni, the broad muscles of the abdomen, rectus abdominis, sacro-lumbalis, longissimus dorsi, serratus posticus inferior, &c. Haller[1] conceived that the ribs, in expiration, are successively depressed towards the last rib; which is first fixed by the abdominal muscles and quadratus lumborum. The intercostal mus-

[1] Element. Physiol., viii. 4, Lausann., 1764.

cles then act, and draw the ribs successively downwards. M. Magendie[1] contests the explanation of Haller; and the truth would seem to be, that the muscles just mentioned, participate with the intercostals in every expiratory movement. By this action, the capacity of the chest is diminished; the lungs are correspondently pressed upon, and the air issues by the glottis. It has been already remarked, that, during expiration, the arytenoidei muscles contract, and the glottis appears to close. Still, space sufficient is left to permit the exit of the air.

It has been asked:—Is the air expired precisely that which has been taken in by the previous inspiration? It is impossible to empty the lungs wholly by the most forced expiration. A portion still remains; and hence it has been assumed, that the use of inspiration is to constantly renew the air remaining in the air-cells. On this subject we are not well-informed; but it is probable, that the lighter and more rarefied air mixes, by diffusion, with the newly-arrived and denser. Many experiments have been made to determine the change of bulk which air experiences by being respired. According to Sir Humphry Davy,[2] it is diminished, by a single inspiration, from $\frac{1}{70}$th to $\frac{1}{100}$th part of its bulk. Cuvier makes it about $\frac{1}{50}$th; Allen and Pepys a little more than one-half per cent. Berthollet from 0·69 to 3·70 per cent.; and Bostock $\frac{1}{50}$th,—as the average diminution. Assuming this last estimate to be correct, and forty cubic inches to be the quantity drawn into the lungs at each inspiration, it would follow, that half a cubic inch disappears each time we respire. This, in a day, would amount to 14,400 cubic inches, or to rather more than eight cubic feet. The experiments of MM. Dulong and Despretz make the diminution considerable. The latter gentleman placed six small rabbits in forty-nine quarts of air for two hours, at the expiration of which time the air had diminished one quart. A portion of the inspired air must, consequently, be absorbed.

In the ordinary respiration of men from seventeen to thirty-three years old, Valentin[3] has calculated, from the watery vapour contained in the saturated expired air, that the average quantity of air expired in a minute is 400 cubic inches,—the extremes under varying circumstances being 234 and 686 cubic inches, and the average quantity of one ordinary expiration 31·1 cubic inches; the extremes in very tranquil and somewhat hurried respiration 11·4 and 74 cubic inches. Mr. Paget,[4] however, thinks that Mr. Coathupe's[5] estimate of 20 to 25 cubic inches is probably better, inasmuch as it was drawn from the results of respiration continued during a longer period and with less restraint than in the experiments of Valentin.

Of late, some interesting experiments have been made by Dr. Hutchinson,[6] with an instrument somewhat unhappily termed by him a *spirometer*, by which he measures the quantity of air expired in a full

[1] Précis, &c., ii. 324.
[2] Researches, Chemical and Philosophical, p. 431, Lond., 1800.
[3] Lehrbuch der Physiologie des Menschen, i. 542, Braunschweig, 1844.
[4] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 128, Philad., 1849.
[5] Philos. Magazine, June, 1839.
[6] Medico-Chirurgical Review, xxix. p. 237, Lond., 1846.

and forcible expiration, and which he esteems an index of the *vital capacity*, as it expresses the power which a person has of breathing in the exigencies of active exercise, violence, and disease. From the results of 1923 observations made on males, he has inferred, that for every inch of height—from five feet to six—eight additional cubic inches of air at 60° Fahr. are given out by a forced expiration; so that, he believes, from the height alone of an adult male, he can pronounce what quantity of air he should breathe when healthy.

Dr. Hutchinson gives the following table of the quantity of air, expelled by the strongest expiration after the deepest inspiration, for every inch of height between five and six feet, as ascertained by actual observation with the spirometer, and as calculated by the rule of progression referred to above.

Height.	From Observation.	Regular Progression.
Ft. in. Ft. in.	*Cub. in.*	*Cub. in.*
5 0 to 5 1	174	174
5 1 " 5 2	177	182
5 2 " 5 3	189	190
5 3 " 5 4	193	198
5 4 " 5 5	201	206
5 5 " 5 6	214	214
5 6 " 5 7	229	222
5 7 " 5 8	228	230
5 8 " 5 9	237	238
5 9 " 5 10	246	246
5 10 " 5 11	247	254
5 11 " 6 0	259	262

Dr. Hutchinson found, that two other conditions influence the quantity of air that passes to and from the lungs in forced voluntary respiration,—weight, and age. The former does not affect the respiratory power of an individual of any height between five feet one inch and five feet eleven inches, until it has increased seven per cent. above the average weight of the body in persons of that height; but, beyond this, it diminishes in the ratio of one cubic inch per pound for the next 35 pounds,—the limit of his calculations. In males of the same height the respiratory power is increased from 15 to 35 years of age; but from 35 to 65 years it decreases nearly $1\frac{1}{2}$ cubic inch for each year;[1] and the results of the examinations are so nearly uniform, that it has been inferred, disease may be suspected in any man who cannot blow out nearly as many cubic inches as the average of those of the same height, even when by external measurement his chest appears to be of full size. The size of the chest is, indeed, stated to afford no good indication of the capacity of expiration. The only exceptions among the healthy to the general rule of the direct proportion between the height of the body and the capacity of expiration, are in the cases of fat persons, whose capacity is always low. It was the observation—made by M. Bourgery[2]—that thin men have the greatest capacity of respiration, which first led Dr. Hutchinson to the experiments, that furnished the law given above. He found, that the

[1] For the quantity of air inspired and expired in forced respiration, see Hales, Statical Essays, i. 242, and Bostock, System of Physiology, p. 316, Lond., 1836.

[2] Archiv. Générales de Médecine, Mars, 1843.

full expiratory force of a healthy man is commonly about one-third greater than his inspiratory force; and he states, that whenever the expiratory are not stronger than the inspiratory muscles, some disease is present. In examining the results of all his experiments—1500 in number—he found the power of the inspiratory muscles was greatest in men of five feet nine inches in height,—their inspiratory powers being equal, on an average, to a column of 2·75; and their expiratory power to one of 3·97 inches of mercury; whilst in four of the classes, composed generally of active, efficient and healthy individuals, namely Firemen, Metropolitan Police, Thames Police, and Royal Horse Guards, the inspiratory power of the men of five feet seven inches was the greatest, being equal to 3·07 inches of mercury; and those of five feet eight inches to 2·96, or nearly three inches. The average power of the five feet seven inches and five feet eight inches men of all classes examined was only 2·65 inches of mercury. He infers, from all his experiments, that a healthy man of the height of five feet seven inches or five feet eight inches ought to elevate by inspiration a column of mercury of three inches.

The experiments of Valentin[1] and Mendelssohn,[2] as far as they go, confirm those of Dr. Hutchinson.

Attempts have been made to estimate the quantity of air remaining in the lungs after respiration; but the sources of discrepancy are here as numerous as in the cases of inspiration or expiration. Goodwyn[3] estimated it at 109 cubic inches: Menzies[4] at 179; Jurin[5] at 220; Fontana[6] at 40; and Cuvier, after a forced inspiration, at from 100 to 60. Davy[7] concluded, that his lungs, after a forced expiration, still retained 41 cubic inches of air; and after a natural expiration 118 cubic inches; after a natural inspiration, 135; and after a forced inspiration, 254. Vierordt[8] supposes that the residual air after the deepest expiration is about 36.600 cubic inches. By a full forced expiration after a forced inspiration, he expelled 190 cubic inches; after a natural inspiration, 78·5; and after a natural expiration, 67·5. Mr. Julius Jeffreys[9] divides the air of respiration into four quantities—*First*, the *residual air*, or that which cannot be expelled from the lungs, but remains after a full and forcible expiration; which he estimates at 120 cubic inches—*Secondly*, the *supplementary air*,—*reserve air* of Dr. Hutchinson—or that which can be expelled by a forcible expiration, after an ordinary outbreathing, valued at 130 cubic inches—*Thirdly*, the *breath*, or *tidal air*,—*breathing air* of Dr. Hutchinson—valued at 26 cubic inches; and *Fourthly*, the *complementary* or *complemental air*, or that which can be inhaled after an ordinary inspiration, which amounts to 100 cubic inches.

[1] Lehrbuch der Physiologie des Menschen, i. 524, Braunschweig, 1844.

[2] Der Mechanismus der Respiration und Circulation, Berlin, 1845; cited by Dr. John Reid, op. cit., p. 336.

[3] Op. citat., p. 36.

[4] Op. citat., p. 31.

[5] Philosoph. Trans., vol. xxx. p. 758.

[6] Philos. Trans. for 1799, p. 355.

[7] Op. citat., p. 411.

[8] Art. Respiration, in Wagner's Handwörterbuch der Physiologie, u. s. w. 12te Lieferung, Braunschweig, 1845.

[9] Views upon the Statics of the Human Chest, &c., London, 1843.

This estimate gives 250 cubic inches as the average volume which the chest contains after an ordinary expiration.

It is impossible, from such variable data as the above, to deduce any thing like a satisfactory conclusion; but if we assume with Dr. Bostock, and Dr. Thomson[1] is disposed to adopt the estimate, 170 cubic inches as the quantity that may be forcibly expelled, and that 120 cubic inches will be left in the lungs, we shall have 290 cubic inches as the measure of the lungs in their natural or quiescent state; to this quantity 40 cubic inches are added by each ordinary inspiration, giving 330 cubic inches as the measure of the lungs in their distended state. Hence it would seem, that about one-eighth of the whole contents of the lungs is changed by each respiration; and that rather more than two-thirds can be expelled by a forcible expiration. Supposing that each act of respiration occupies three seconds, or that we respire twenty times in a minute, a quantity of air, rather more than $2\frac{3}{4}$ times the whole contents of the lungs, will be expelled in a minute, or about four thousand times their bulk in twenty-four hours. The quantity of air respired during this period will be 1,152,000 cubic inches, about $666\frac{1}{2}$ cubic feet. Such is Dr. Bostock's estimate.

It is the residuary air, that gives to the lungs the property of floating on the surface of water, after they have once received the breath of life; and no pressure can force out the air, so as to make them sink. Hence, the chief proofs, whether a child has been born alive or dead, are deduced from the lungs. These constitute *docimasia pulmonum*, Lungenprobe or Athemprobe, ("Lung-proof or Respiration-proof,") of the Germans.

Expiration, like inspiration, has been divided into three grades; *ordinary*, *free*, and *forced;* but it must necessarily admit of multitudinous shades of difference. In *ordinary* passive respiration, expiration is effected solely by the relaxation of the diaphragm. In *free* active respiration, the muscles that raise the ribs are likewise relaxed, and there is a slight action of the direct expiratory muscles. In *forced* expiration, all the respiratory muscles are thrown into action. In this manner, the air makes its way along the air passages through the mouth or nostrils, or both; carrying with it a fresh portion of the halitus from the mucous membrane. This it deposits when the atmosphere is colder than the temperature acquired by the respired air, and if the atmosphere be sufficiently cold, as in winter, the vapour becomes condensed as it passes out, and renders expiration visible.

Dr. Hutchinson[2] measured the costal movement during ordinary respiration in healthy males, and found it not to exceed from two to four-tenths of a line. He states, that the difference between the circumference of an ordinary man's chest measured over the nipples in the two states of a deep inspiration and a deep expiration amounts to three inches; and Valentin,[3] under the same circumstances, found the average difference in the circumference of the chest, measured over the

[1] System of Chemistry, vol. iv.

[2] Medico-Chirurgical Transactions, xxix. 187, Lond., 1846.

[3] Lehrbuch der Physiologie des Menschen, i. 541, Braunschweig, 1844.

scrobiculus cordis, in seven individuals of the male sex between $17\frac{1}{2}$ and 33 years of age, to be as 1 : 8·29 of the whole circumference.

If the whole time occupied by a respiratory act,—that is, from the beginning of one inspiration to the beginning of the next,—be represented by 10, the time occupied by the inspiratory movement has been estimated approximately at 5; that of the expiratory at 4; and the pause between the expiratory and succeeding inspiratory movement at 1.

The number of respirations in a given time differs considerably in different individuals. Dr. Hales,[1] Dr. Dalton,[2] Mr. Coathupe[3] and Dr. Bostock[4] reckon them at twenty. Laënnec from 12 to 15. A man, on whom Menzies made experiments, breathed only fourteen times in a minute. Sir Humphry Davy[5] made between twenty-six and twenty-seven in a minute. Dr. Thomson,[6] and Allen and Pepys, about nineteen; and Magendie,[7] fifteen. In 1714 adults of the male sex considered to be in a state of health Dr. Hutchinson[8] found, that the majority, in the sitting posture, breathed between 16 and 24 in the minute; and of these a great number 20 per minute. Vierordt[9] found the number in his own person to be, on an average, $11\frac{9}{10}$ths when sitting and the mind disengaged; whilst the maximum was 15, and the minimum 9. Our own average is about sixteen; and this is the average, in the adult, assumed by Günther[10] and Berthold.[11] That, deduced from the few observers, who have recorded their observations,—twenty per minute,—has generally been taken; but we are satisfied it is above the truth; eighteen would be nearer the general average, and it has accordingly been admitted by many. Eighteen in a minute give twenty-five thousand nine hundred and twenty in the twenty-four hours. The number is influenced, however, by various circumstances. The child and the female, and perhaps also the aged, breathe more rapidly than the adult male. MM. Hourmann and Dechambre[12] examined two hundred and fifty-five women between the ages of sixty and ninety-six, the average number of whose respirations was 21·79 per minute. We find as much variety in men as we do in horses: whilst some are short, others are long-winded; and this last condition may be improved by appropriate *training*, to which the pedestrian and the prize-fighter, equally with the horse, are subjected for some time before they are called upon to test their powers. In sleep, the respiration is generally deeper, less frequent, and appears to be performed greatly by the intercostals and diaphragm.[13] Motion has also a sensible effect in hurrying the respiration, as well as

[1] Statical Essays, 3d edit., i. 243.
[2] Memoirs of the Literary and Philosophical Society of Manchester, 2d series, ii. 26, Manchester, 1813.
[3] Lond. and Edinb. Philos. Magaz., xiv. 401, 1839.
[4] System of Physiology, p. 321, Lond., 1836.
[5] Researches chiefly concerning Nitrous Oxide, p. 434, Lond., 1800.
[6] System of Chemistry, iv. 604, Glasgow, 1820.
[7] Précis de Physiologie, 2de édit., Paris, 1825.
[8] Op. cit., p. 226.
[9] Wagner's Handwörterbuch der Physiologie, art. Respiration, ii. 834, Braunschweig, 1845.
[10] Lehrbuch der Physiologie des Menschen, 2 Band., 1 Abtheil., s. 217, Leipzig, 1848.
[11] Lehrbuch der Physiologie, dritte Auflage, 2ter Theile, s. 227, Götting., 1848.
[12] Archiv. Génér. de Médecine, Nov., 1835.
[13] Adelon, Physiologie de l'Homme, iii. 185.

distension of the stomach by food, certain mental emotions, &c.: its condition during disease becomes also a subject of interesting study to the physician, and one that has been much facilitated by the acoustic method introduced by Laënnec. To his instrument—the *stethoscope*—allusion has already been made. By it, or by the ear applied to the chest, we are able to hear distinctly the respiratory murmur and its modifications; and thus to judge of the nature of pulmonary affections. But this is a topic that appertains more especially to pathology.

(3.) RESPIRATORY PHENOMENA CONCERNED IN CERTAIN FUNCTIONS.

There are certain respiratory movements, concerned in effecting other functions, that require consideration. Some of these have already been discussed. M. Adelon[1] has classed them into: *First.* Those employed in the *sense of smell*, either for the purpose of conveying the odorous molecules into the nasal fossæ; or to repel them and prevent their ingress. *Secondly.* The inspiratory actions employed in the *digestive function*, as in *sucking*. *Thirdly.* Those connected with muscular motion when forcibly exerted; and particularly with *straining* or the employment of *violent effort*. *Fourthly.* Those concerned in the various *excretions*, either voluntary,—as in *defecation* and *spitting;* or involuntary,—as in *coughing*, *sneezing*, *vomiting*, *accouchement*, &c.; and *lastly*, those that constitute phenomena of *expression*,—as *sighing*, *yawning*, *laughing*, *crying*, *sobbing*, &c. Some of these, that have already engaged attention, do not demand comment; others are topics of considerable interest, and require investigation.

1. *Straining.*—The state of respiration is much affected during the more active voluntary movements. Muscular exertion of whatever kind, when considerable, is preceded by a long and deep inspiration; the glottis is closed; the diaphragm and respiratory muscles of the chest are contracted, as well as the abdominal muscles which press upon the contents of the abdomen in all directions. Whilst the proper respiratory muscles are exerted, those of the face participate, owing to their association through the medium of particular nerves. By this series of actions, the chest is rendered capacious; and the force that can be developed is augmented, in consequence of the trunk being rendered immovable as regards its individual parts,—thus serving as a fixed point for the muscles that arise from it, so that they are enabled to employ their full effort.[2] The physiological state of muscular action, as connected with the mechanical function of respiration, is happily described by Shakspeare, when he makes the fifth Harry encourage his soldiers at the siege of Harfleur.

> "Stiffen the sinews, summon up the blood;
> Now set the teeth, and stretch the nostrils wide;
> Hold hard the breath and bend up every spirit
> To its full height." KING HENRY V. iii. 1.

In the effort required for effecting the various excretions, a similar action of the respiratory muscles takes place. The organs, from which

[1] Op. cit., p. 188.
[2] Ibid., p. 190; and art. Effort, in Dict. de Méd., 2de édit., xi. 197, Paris, 1835.

these excretions have to be removed, are either in the thorax or abdomen; and in all cases have to be compressed by the parietes of those cavities. A full inspiration is first made; the expiratory muscles, with those that close the glottis, are then forcibly and simultaneously contracted, and by this means the thoracic and abdominal viscera are compressed. Some difference, however, exists, according as the viscus to be emptied is seated in the abdomen or thorax. In the evacuation of the fæces, the lungs are first filled with air; and whilst the muscles of the larynx contract to close the glottis, those of the abdomen contract also; and as the lung, in consequence of the included air, resists the ascent of the diaphragm, the compression bears upon the large intestine. The same happens in the excretion of the urine, and in accouchement.

2. *Coughing* and *Sneezing.*—When the organs that have to be cleared are the air-passages,—as in *coughing* to remove mucus from them,—the same action of the muscles of the abdomen is invoked; but the glottis is open to allow the exit of the mucus. In this case, the expiratory muscles contract convulsively and forcibly, so that the air is driven violently from the lungs; and, in its passage, sweeps off the irritating matter, and conveys it out of the body. To aid this, the muscular fibres, at the posterior part of the trachea and larger bronchial tubes, contract, so as to diminish the calibre of these canals; and in this way expectoration is facilitated. The action differs, however, according as the expired air is sent through the nose or mouth; in the former case, constituting *sneezing;* in the latter, *coughing.* The former is more violent than the latter, and is involuntary; whilst the latter is not necessarily so. In both cases the movement is excited by some external irritant, applied directly to the mucous membrane of the windpipe or nose; or by some modified action in the very tissue of the part, which acts as an irritating cause. In both cases the air is driven forcibly forwards; and both are accompanied by sounds that cannot be mistaken. In these actions, we have striking exemplifications of the extensive association of muscles, through the medium of nerves, to which we have so often alluded. The pathologist, too, has repeated opportunities for observing the extensive sympathy between distant parts of the frame, as indicated by the actions of sneezing and coughing, especially of the former. If a person be exposed for a short period to the partial and irregular application of cold, so that the capillary action of a part of the body is modified, as where we get the feet wet, or sit in a draught of air, a few minutes is frequently sufficient to exhibit sympathetic irritation in the Schneiderian membrane of the nose, and sneezing. Nor is it necessary, that the capillary action of a distant part shall be modified by the application of cold. We have had the most positive evidence, that if the capillary circulation be irregularly excited, even by the application of heat, whilst the rest of the body is receiving none, inflammation of the mucous membrane of the nasal fossæ and fauces may supervene with no less certainty.

3. *Blowing the Nose.*—The substance that has to be excreted by this operation is composed of the nasal mucus, the tears sent down the ductus ad nasum, and the particles deposited on the membrane by the

air in its passage through the nasal fossæ. Commonly, these secretions are only present in quantity sufficient to keep the membrane moist, the remainder being evaporated or absorbed. Frequently, however, they exist in such quantity as to fall by their own gravity into the pharynx, where they are sent down into the stomach by deglutition, are thrown out at the mouth, or make their exit at the anterior nares. To prevent this last effect more especially, we have recourse to blowing the nose. This is accomplished by taking in air, and driving it out suddenly and forcibly, closing the mouth at the same time, so that the air may issue by the nasal fossæ and clear them; the nose being compressed so as to make the velocity of the air greater, as well as to express all the mucus that may be forced forwards.

4. *Spitting* differs somewhat according to the part in which the mucus or matter to be ejected is seated. At times, it is exclusively in the mouth; at others, in the back part of the nose, pharynx, or larynx. When the mucus or saliva of the mouth has to be excreted, the muscular parietes of the cavity, as well as the tongue, contract so as to eject it from the mouth; the lips being at times approximated, so as to render the passage narrow, and impel the sputa more strongly forward. The air of expiration may be, at the same time, driven forcibly through the mouth, so as to send the matter to a considerable distance. The practised spitter sometimes astonishes us with the accuracy and power of propulsion of which he is capable. When the matter to be evacuated is in the nose, pharynx, or larynx, it requires to be brought, first of all, into the mouth. If in the posterior nares, the mouth is closed, and the air is drawn in forcibly through the nose, the pharynx being at the same time constricted so as to prevent the substances from passing down into the œsophagus. The pharynx now contracts from below to above, in an inverse direction to that required in deglutition; and the farther excretion from the mouth is effected in the manner just described.

Where the matters are situate in the air passages, the action may consist in coughing; or, if higher up, simply in *hawking*. A forcible expiration, unaccompanied by cough, is, indeed, in many cases, sufficient to detach the superfluous mucous secretion from even the bronchial tubes. In hawking, the expired air is sent forcibly forwards, and the parts about the fauces are suddenly contracted so as to diminish the capacity of the tube, and propel the matter onwards. The noise is produced by their discordant vibrations. Both these modes bear the general name of *expectoration*.

When these secretions are swallowed, they are subjected to the digestive process; a part is taken up, and the remainder rejected; so that they belong to the division of *recremento-excrementitial fluids* of some physiologists.

(4.) RESPIRATORY PHENOMENA CONNECTED WITH EXPRESSION.

It remains to speak of the expiratory phenomena that strictly form part of the function of expression, and depict the moral feeling of the individual who gives them utterance.

1. *Sighing* consists of a deep inspiration, by which a large quantity of air is received slowly and gradually into the lungs, to compensate

for the deficiency in the due aeration of the blood which precedes it. The most common cause of sighing is mental uneasiness; it also occurs at the approach of sleep, or immediately after waking. In all these cases, the respiratory efforts are executed more imperfectly than under ordinary circumstances; the blood, consequently, does not circulate through the lungs in due quantity, but accumulates more or less in these organs, and in the right side of the heart; and it is to restore the due balance, that a deep inspiration is now and then established.

2. *Yawning*, *oscitancy*, *oscitation*, or *gaping*, is a full, deep, and protracted inspiration, accompanied by a wide separation of the jaws, and followed by a prolonged and sometimes sonorous expiration. It is excited by many of the same causes as sighing. It is not, however, the expression of a depressing passion, but is occasioned by any circumstance that impedes the necessary aeration of the blood; whether it be retardation of the action of the respiratory muscles, or the air being less rich in oxygen. Hence we yawn at the approach of sleep, and immediately after waking. The inspiratory muscles, fatigued from any cause, experience some difficulty in dilating the chest; the lungs are, consequently, not properly traversed by the blood from the right side of the heart; oxygenation is, therefore, not duly effected and an uneasy sensation is induced; this is put an end to by the action of yawning, which allows the admission of a considerable quantity of air. We yawn at the approach of sleep, because the agents of respiration, becoming gradually more debilitated, require to be now and then excited to fresh activity, and the blood needs the requisite aeration. Yawning on waking seems to be partly for the purpose of arousing the respiratory muscles to greater activity, the respiration being always slower and deeper during sleep. It is, of course, impossible to explain why the respiratory nerves should be chiefly concerned in these respiratory movements of an expressive character. The fact, however, is certain; and it is remarkably proved by the circumstance, that yawning can be excited by even looking at another affected in this manner; nay, by simply looking at a sketch, and even thinking of the action. The same also applies to sighing and laughing, and especially to the latter.

3. *Pandiculation* or *stretching* is a frequent concomitant of yawning, and appears to be established instinctively to arouse the extensor muscles to a balance of power, when the action of the flexors has been predominant. In sleep, the flexor muscles exercise that preponderance which, in the waking state, is exerted by the extensors. This, in time, is productive of some uneasiness; and, hence, occasionally during sleep, but still more at the moment of waking, the extensor muscles are roused to action to restore the equipoise; or, perhaps, as the muscles of the upper extremities, and those engaged directly or indirectly in respiration, are chiefly concerned in the action, it is exerted for the purpose of exciting the respiratory muscles to increased activity.

By Dr. Good,[1] yawning and stretching have been regarded as morbid affections and amongst the signs of debility and lassitude:—"Every one," he remarks, "who resigns himself ingloriously to a life of lassi-

[1] Study of Medicine, class 4, ord. 3, gen. 2, sp. 6.

tude and indolence, will be sure to catch these motions as a part of that general idleness which he covets; and, in this manner, a natural and useful action is converted into a morbid habit; and there are loungers to be found in the world, who, though in the prime of life, spend their days as well as their nights in a perpetual routine of these convulsive movements, over which they have no power; who cannot rise from the sofa without stretching their limbs, nor open their mouths to answer a plain question without gaping in one's face. The disease is here idiopathic and chronic; it may perhaps be cured by a permanent exertion of the will, and ridicule or hard labour will generally be found the best remedies for calling the will into action."

4. *Laughing* is a convulsive action of the muscles of respiration and voice, accompanied by a facial expression, which has been explained elsewhere. It consists of a succession of short, sonorous expirations. Air is first inspired so as to fill the lungs. To this succeed short, interrupted expirations, with simultaneous contractions of the muscles of the glottis, so that the aperture is slightly contracted, and the lips assume the tension necessary for the production of sound. The interrupted character of the expirations is caused by convulsive contractions of the diaphragm, which constitute the greater part of the action. In very violent laughter, the respiratory muscles are thrown into such forcible contractions, that the hands are applied to the sides to support them. The convulsive action of the thorax likewise interferes with the circulation through the lungs; the blood, consequently, stagnates in the upper part of the body; the face becomes flushed; the sweat trickles down the forehead, and the eyes are suffused with tears; but this is apparently owing in part to mechanical causes; not to the lachrymal gland being excited to unusual action, as in weeping. At times, however, we find the latter cause in operation, also.

5. *Weeping.* The action of weeping is very similar to that of laughing; although the causes are so dissimilar. It consists in an inspiration, followed by a succession of short, sonorous expirations. The facial expression, so diametrically opposite to that of laughter, has been depicted in another place.

Laughter and weeping appear to be characteristic of humanity. Animals shed tears, but the act does not seem to be accompanied by the mental emotion that characterizes crying in the sense in which we employ the term. It has, indeed, been affirmed by Steller,[1] that the *phoca ursina* or *ursine seal;* by Pallas,[2] that the camel; and by Von Humboldt,[3] that a small American monkey, shed tears when labouring under distressing emotions. The last scientific traveller states, that "the countenance of the *titi* of the Orinoco,—*simia sciurea* of Linnæus,—is that of a child; the same expression of innocence; the same smile; the same rapidity in the transition from joy to sorrow. The Indians affirm, that it weeps like man, when it experiences chagrin; and the remark is accurate. The large eyes of the ape are suffused

[1] Nov. Comm. Academ. Scient. Petropol., ii. 353.
[2] Sammlungen Historisch. Nachricht. über die Mongolischen Völkerschaften, Th. i. 177.
[3] Recueil d'Observations de Zoologie, &c., i. 333.

with tears, when it experiences fear or any acute suffering." Shakspeare's description of the weeping of the stag,—

"That from the hunter's aim had ta'en a hurt,"

is doubtless familiar to most of our readers.

"The wretched animal heaved forth such groans,
That their discharge did stretch his leathern coat
Almost to bursting; and the big, round tears
Coursed one another down his innocent nose[1]
In piteous chase; and thus the hairy fool,
Much marked of the melancholy Jaques,
Stood on th' extremest verge of the swift brook,
Augmenting it with tears."
As You Like It, ii. 1.

We have less evidence in favour of the laughter of animals. Le Cat,[2] indeed, asserts, that he saw the chimpanzee both laugh and weep. The orang, carried to Great Britain from Batavia by Dr. Clarke Abel, never laughed; but he was seen occasionally to weep.[3]

6. *Sobbing* still more resembles laughing, except that, like weeping, it is usually indicative of the depressing passions; and generally accompanies weeping. It consists of a convulsive action of the diaphragm; which is alternately raised and depressed, but to a greater extent than in laughing, and with less rapidity. It is susceptible of various degrees, and has the same physical effects upon the circulation as weeping. Dr. Wardrop[4] considers laughter, crying, weeping, sobbing, sighing, &c., as efforts made with a view to effect certain alterations in the quantity of blood in the lungs and heart, when the circulation has been disturbed by mental emotions.

7. *Panting* or *anhelation* consists in a succession of alternate, quick, and short inspirations and expirations. Its physiology, however, does not differ from that of ordinary respiration. The object is, to produce a frequent renewal of air in the lungs, in cases where the circulation is unusually rapid; or where, owing to disease of the thoracic viscera, a more than ordinary supply of fresh air is demanded. We can, hence, understand why dyspnœa should be one of the concomitants of most of the severe diseases of the chest; and why it should occur whenever the air we breathe does not contain a sufficient quantity of oxygen. The panting, produced by running, is owing to the necessity for keeping the chest as immovable as possible, that the whole effort may be exerted on the muscles of locomotion; and thus suspending, for a time, the respiration, or admitting only of its imperfect accomplishment. This induces an accumulation of blood in the lungs and right side of the heart; and panting is the consequence of the augmented action necessary for transmitting it through the vessels.

[1] "The alleged 'big round tears,' which 'course one another down the innocent nose' of the deer, the hare, and other animals, when hotly pursued, are in fact only sebaceous matter, which, under these circumstances, flows in profusion from a collection of follicles in the hollow of the cheek."—Fletcher's Rudiments of Physiology, part ii. *b.* p. 50, Edinb., 1836.

[2] Traité de l'Existence du Fluide des Nerfs, p. 35.

[3] Lawrence, Lectures on Physiology, Zoology, and the Natural History of Man, p. 236, Lond., 1814.

[4] On the Nature and Treatment of Diseases of the Heart, part i. p. 62, Lond., 1837.

b. *Chemical Phenomena of Respiration.*

Having studied the mode in which air is received into, and expelled from, the lungs, we have now to inquire into the changes produced on the venous blood—containing the products of the various absorptions—in the lungs; as well as on the air itself. These changes are effected by the function of *sanguification*, *hæmatosis*, *respiration* in the restricted sense in which it is employed by some, *arterialization*, *decarbonization*, *aëration*, *atmospherization*, &c., of the blood. With the ancients this process was but little understood. It was generally believed to be the means of cooling the body; and, in modern times, Helvetius revived the notion, attributing to it the office of refrigerating the blood,—heated by its passage through the long and narrow channels of the circulation,—by the cool air constantly received into the lungs. The reasons, which led to this opinion, were:—that the air, which enters the lungs in a cool state, issues warm; and that the pulmonary veins, which convey the blood from the lungs, are of less dimension than the pulmonary artery, which conveys it to them. From this it was concluded, that the blood, during its progress through the lungs, must lose somewhat of its volume, or be condensed by refrigeration. The warmth of the expired air can, however, be readily accounted for; and it is not true that the pulmonary veins are smaller than the pulmonary artery. The reverse is the fact; and it is obvious, that the doctrine of Helvetius does not explain how we can exist in a temperature superior to our own; which, in his hypothesis, ought to be impracticable.[1]

Another theory, which prevailed for some time, was;—that during inspiration the vessels of the lungs are deployed or unfolded, as it were, and that thus the passage of the blood from the right side of the heart to the left, through the lungs, is facilitated. Its progress was, indeed, conceived to be impossible during expiration, in consequence of the considerable flexures of the pulmonary vessels. The discovery of the circulation of the blood gave rise to this theory; and Haller[2] attaches importance to it, when taken in connexion with the changes effected upon the blood in the vessels. It is incorrect, however, to suppose, that the circulation of the blood through the lungs is mechanically interrupted, when respiration is arrested. The experiments of Drs. Williams[3] and Kay[4] would seem to show, that the interruption is ascribable to the non-conversion of venous into arterial blood, and to the non-adaptation of the radicles of the pulmonary veins for any thing but arterial blood, owing to which causes stagnation of blood supervenes in the pulmonary radicles. Numerous other objections might be made to this view. In the first place, it supposes, that the lungs are emptied at each expiration; and, again, if a simple deploying or unfolding of the vessels were all that is required, any gas ought to be sufficient for respiration—which is not the fact.

[1] Adelon, Physiologie de l'Homme, edit. cit., iii. 201.
[2] Element. Physiol., lib. viii. sect. iv., Lausann., 1766.
[3] Edinburgh Medical and Surgical Journal, vol. lxxvii., 1823.
[4] Edinburgh Med. and Surg. Journal, vol. xxix.; and Physiology and Pathology, &c., of Asphyxia, Lond., 1834.

In these different theories, the principal object of respiration is overlooked—the conversion of the venous blood, conveyed to the lungs by the pulmonary artery, into arterial blood. This is effected by the contact of the inspired air with the venous blood; in which they both lose certain elements, and gain others. Most physiologists have considered that the whole function of hæmatosis is effected in the lungs. M. Chaussier,[1] however, has presumed, that some kind of elaboration is effected on the air, in passing through the cavities of the nose and mouth, and the different bronchial ramifications, by being agitated with the bronchial mucus; similar to what he conceives is effected by the mucus on the aliment in its passage from the mouth to the stomach; but his view is conjectural in both one case and the other. M. Legallois,[2] again, thought, that hæmatosis commences at the part, where the chyle and lymph are mixed with the venous blood, or in the subclavian vein. This admixture, he conceives, occurs more or less immediately; is aided in the heart, and the conversion is completed in the lungs. To this belief he was led by the circumstance, that when the blood quits the lungs it is manifestly arterial; and he thought, that what the products of absorption lose or gain in the lungs is too inconsiderable to account for the important and extensive change; and that therefore it must have commenced previously. Facts, however, are not exactly in accordance with the view of Legallois. They seem to show, that the blood of the pulmonary artery is analogous to that of the subclavian vein; and hence it is probable, that there is no other action exerted upon the fluid in this part of the venous system, than a more intimate admixture of the venous blood with the chyle and lymph in their passage through the heart.

The changes, wrought on the air by respiration, are considerable. It is immediately deprived of a portion of both of its main constituents—oxygen and nitrogen; and it always contains, when expired, a quantity of carbonic acid greater than it had when received into the lungs, along with an aqueous and albuminous exhalation to a considerable amount.

Oxygen is consumed in the respiration of all animals, from the largest quadruped to the most insignificant insect; and if we examine the expired air, the deficiency is manifest. Many attempts have been made to estimate the precise quantity consumed during respiration; but the results vary essentially from each other; partly owing to the fact, that the amount consumed by the same animal differs in different circumstances. Menzies[3] was probably the first that attempted to ascertain the quantity consumed by man in a day. According to him, 36 cubic inches are expended in a minute; consequently, 51,840 in the twenty-four hours, equal to 17,496 grains. Lavoisier[4] makes it 46,048 cubic inches, or 15,541 grains. This was the result of his earlier experiments; and, in his last, which he was executing at the time when he fell a victim to the tyranny of Robespierre, he made it 15592·5 grains; corresponding greatly with the results of his earlier observa-

[1] Adelon, Physiologie de l'Homme, iii. 205.

[2] Annales de Chimie, iv. 115.

[3] Dissertation on Respiration, p. 21, Edin., 1796.

[4] Mémoir de l'Academ. des Sciences, 1789, 1790.

tions. The experiments of Sir Humphry Davy[1] coincide greatly with those of Lavoisier. He found the quantity consumed in a minute to be 31·6 cubic inches; making 45,504 cubic inches, or 15,337 grains in twenty-four hours. The results obtained by Messrs. Allen and Pepys[2] make it much less. They consider the average consumption to be, in the twenty-four hours, under ordinary circumstances, 39,534 cubic inches, equal to 13,343 grains.

If we regard the experiments of Lavoisier and Davy, between which there is the greatest coincidence, to be an approximation to the truth, it will follow, that, in a day, a man consumes rather more than 25 cubic feet of oxygen; and as the oxygen amounts to only about one-fifth of the respired air, he must render 125 cubic feet of air unfit for supporting combustion and respiration.

The experiments of Crawford, Jurine, Lavoisier and Séguin, Prout, Fyfe, and Edwards,[3] have proved, that the quantity of oxygen consumed varies according to the condition of the functions and the system generally. Séguin[4] found, that muscular exertion increases it nearly fourfold. Dr. Prout,[5] who gave much attention to the subject, was induced to conclude, from his experiments, that moderate exercise increases it; but if the exercise be continued so as to induce fatigue, a diminished consumption takes place. The exhilarating passions appeared to increase the quantity; whilst the depressing passions and sleep, the use of alcohol and tea, diminished it. He discovered, that the quantity of oxygen consumed is not uniformly the same during the twenty-four hours. Its maximum occurred between 10 A. M. and 2 P. M., or generally between 11 A. M. and 1 P. M.: its minimum commenced about 8½ P. M., and it continued nearly uniform till about 3½ A. M. Dr. Fyfe[6] found, that the quantity was diminished by a course of nitric acid, by a vegetable diet, and by affecting the system with mercury. Temperature has an influence. Dr. Crawford[7] found, that a Guinea-pig, confined in air at the temperature of 55°, consumed double the quantity which it did in air at 104°. He also observed, in such cases, that venous blood, when the body was exposed to a high temperature, had not its usual dark colour; but, by its florid hue, indicated that the full change had not taken place in its constitution in the course of circulation. The same fact is mentioned by a recent observer, who affirms, that if, when an animal is near dying from the effect of heat, an artery be opened, its blood is as black as that of a vein, and does not become bright by exposure.

We may thus understand the great lassitude and yawning, induced by the hot weather of summer; and the languor and listlessness which are so characteristic of those who have long resided in torrid climes. Dr. Prout conceives, that the presence or absence of the sun alone regulates the variation in the consumption of oxygen which he has described;

[1] Researches, &c., p. 431.
[2] Philos. Transact. for 1808.
[3] De l'Influence des Agens Physiques sur la Vie, p. 410, Paris, 1824; or Hodgkin and Fisher's translation.
[4] Mém. de l'Académ. des Sciences, 1789 and 1790.
[5] Annals of Philos., ii. 330, iv. 331, and xiii. 269.
[6] Annals of Philos., iv. 334, and Bostock's Physiol., i. 350.
[7] Op. cit., p. 387.

but the deduction of Dr. Fleming[1] appears to be more legitimate,—that it keeps pace with the degree of muscular action, and is dependent upon it. Consequently, a state of increased consumption is always followed by an equally great decrease, in the same manner as activity is followed by fatigue.

The disagreement of experimenters, as respects the removal of *nitrogen* or *azote* from the air, during respiration, is still greater than in the case of oxygen. Priestley, Davy, Humboldt, Henderson, Cuvier, and Pfaff, found a less quantity exhaled than was inspired. Spallanzani, Lavoisier and Séguin, Vauquelin, Allen and Pepys, Ellis, Thomson, Valentin and Brunner, and Dalton, inferred that neither absorption nor exhalation takes place,—the quantity of that gas, in their opinion, undergoing no change during its passage through the air-cells of the lungs; whilst Jurine, Nysten, Berthollet, and Dulong and Despretz, on the contrary, found an increase in the bulk of the nitrogen. In this uncertainty, most physiologists have been of opinion that the nitrogen is entirely passive in the function. The facts, ascertained by M. W. F. Edwards,[2] of Paris, shed considerable light on the causes of this discrepancy amongst observers. He has satisfactorily shown that, in the respiration of the same animal, the quantity of nitrogen may be, at one time, augmented; at another, diminished; and, at a third, wholly unchanged. These phenomena he has traced to the influence of the seasons, and he suspects that other causes have a share in their production. In nearly all the lower animals that were the subjects of experiment, an augmentation of nitrogen was observable during summer. Sometimes, it was so slight that it might be disregarded; but, in numerous instances, it was so great as to place the fact beyond the possibility of doubt; and, on some occasions, it almost equalled the whole bulk of the animal. Such were the results of his observations until the close of October, when he noticed a sensible diminution in the nitrogen of the inspired air, and the same continued throughout the whole of winter and beginning of spring. M. Edwards considers it probable, that, in all cases, both exhalation and absorption of nitrogen are going on; that they are frequently accurately balanced, so as to exhibit neither excess nor deficiency of nitrogen in the expired air; whilst, in other cases, depending, as it would appear, chiefly upon temperature, either the absorption or the exhalation is in excess, producing a corresponding effect upon the composition of the air of expiration. MM. Regnault and Reiset,[3] in their experiments on animals, always observed an exhalation of nitrogen; the proportion of which varied—as in the case of carbonic acid formed—with the nature of the food.

Whilst the respired air has lost its oxygenous portion, it has received, as we have remarked, an accession of *carbonic acid*, and, likewise, a quantity of serous vapour. If we breathe through a tube, one end of which is inserted into a vessel of lime-water, the fluid soon becomes milky, owing to the formation of carbonate of lime, which is insoluble in water. Carbonic acid must, consequently, have been given off from

[1] Philosophy of Zoology, i. 355, Edinburgh, 1822.
[2] Op. cit., p. 462.
[3] Comptes Rendus, Paris, 1848.

the lungs. In the case of this gas, again, it has been attempted to compute the quantity formed in the day. Jurine conceived, that the amount, in air once respired in natural respiration, is in the large proportion of $\frac{1}{10}$th or $\frac{1}{12}$th; Menzies, that it is $\frac{1}{20}$th; and, from his estimate of the total quantity of air respired in the twenty-four hours, he deduced the amount of carbonic acid formed to be 51,840 cubic inches, equal to 24105·6 grains. MM. Lavoisier and Séguin,[1] in their first experiments, valued it at 17720·89 grains; but in the next year they reduced their estimate more than one-half;—to 8450·20 grains; and, in Lavoisier's last experiment, it was farther reduced to 7550·4 grains. Sir Humphry Davy's estimate nearly corresponds with that of the first experiment of MM. Lavoisier and Séguin,—17811·36 grains; and Messrs. Allen and Pepys accord pretty nearly with him. These gentlemen found, that air, when inspired, issued, on the succeeding expiration, charged with from 8 to 6 per cent. of carbonic acid; but this estimate greatly exceeds that of Dr. Apjohn,[2] of Dublin, who, in his experiments, found the expired air to contain only 3·6 per cent. The experiments and observations of Messrs. Crawford, Prout, Edwards, and others, to which we have referred—as regards the consumption of oxygen, under various circumstances—apply equally to the quantity of carbonic acid formed, which always bears a pretty close proportion to the oxygen consumed. These experiments also account, in some degree, for the discrepancy in the statements of individuals on this subject.

The experiments of Mr. Coathupe,[3] which were carefully conducted, make the amount of carbonic acid, generated in the 24 hours, about 17·856 cubic inches, that is, 2·616 grains or 5½ ounces of solid carbon. Liebig found the proportion of carbon expired by himself to be 8½ ounces daily; by a soldier, 13½ ounces; by prisoners in close confinement, 7 ounces; and by a boy who took considerable exercise, 9 ounces.[4] More recently, farther experiments have been made on the subject by competent observers. Professor Scharling,[5] of Copenhagen, found, that, at the age of 35, he exhaled 7·7 ounces avoirdupois of carbon in the twenty-four hours—seven of which were passed in sleep. A soldier, 28 years of age, exhaled 8·15 ounces; a lad, of 16, 7·9 ounces; a young woman, aged 19, 5·83 ounces; a boy, 9½ years old, 3·069 ounces; and a girl, 10 years old, 4·42 ounces. In the last two, the time spent in sleep was 9 hours. These amounts, however, were exhaled both from the lungs and cutaneous surface. He constructed an air-tight chamber, of dimensions sufficient to permit him to remain in it for some time without inconvenience. This was connected with an apparatus by which the air was constantly renewed, and the air removed was carefully analyzed, in order to determine the quantity of carbonic acid contained in it. Of the 7·7 ounces exhaled by himself in the twenty-four hours, we may perhaps estimate the amount from

[1] Mémoir. de l'Académ. des Sciences, p. 609, Paris, 1790.
[2] Edinb. Med. and Surg. Journal, Jan., 1831.
[3] Philos. Magazine, June, 1839.
[4] Graham's Elements of Chemistry, Amer. edit., p. 686, Philad., 1843.
[5] Annales des Sciences Naturelles, Février, 1843; cited in Brit. and For. Med. Rev. for July, 1843, p. 285.

the lungs at 5·5 ounces. He infers from all his experiments, that males exhale more carbonic acid than females; and children comparatively more than adults.

MM. Andral and Gavarret undertook a series of interesting experiments on the subject. Their first object was to ascertain the modifying influence of age, sex, and constitution on the quantity of carbonic acid exhaled from the lungs. To determine this, their observations were made under circumstances as uniform as possible; and each experiment was repeated several times on the same subject. The apparatus employed was so devised as to enable the respirations to be freely performed; no portion of the expired air was again inspired; and the greatest care was taken to analyze the expired air with accuracy. The general results obtained by these observers were as follows:—1. The quantity of carbonic acid exhaled by the lungs in a given time varies according to age, sex, and constitution. 2. In both male and female, the quantity undergoes modification, according to the ages of the individuals experimented upon, quite independently of their weights. 3. In all periods of life, there is a difference between the male and female in the amount of carbonic acid exhaled in a given time: *cæteris paribus*, man exhales a much larger quantity than woman. Between the ages of 16 and 40, the former exhales nearly twice as much as the latter. 4. In man, the quantity exhaled goes on regularly increasing from 8 to 30 years of age; and a remarkable augmentation takes place at puberty. After 30, it begins to decrease; and the decrease continues becoming more and more marked as the individual approaches nearer and nearer extreme old age; so that, at this last period, it returns to the standard at which it was about the age of 10. 5. In woman the exhalation augments up to the period of puberty, according to the same law as in man; the increase then suddenly ceases, and the quantity continues at this low standard, with little variation so long as the catamenia appear regularly; but as soon as they cease, the exhalation of carbonic acid from the lungs undergoes a considerable augmentation, after which it decreases as in man, according to the advance of age. 6. During pregnancy, the amount of carbonic acid exhaled is raised temporarily to the standard which it attains after the cessation of the catamenia. 7. In both sexes, and at all ages, the quantity of carbonic acid exhaled by the lungs is greater in proportion to the strength of the constitution, and the developement of the muscular system.

The following table exhibits the amount of solid carbon calculated to be exhaled in one hour at different ages;—the *gramme* is equal to about 15½ grains.

Male.		Female.		
8 years.	5 grammes.	8 years.	5 grammes.	The same standard continues in women during the whole of the menstrual period: but if the catamenia be temporarily suppressed, or pregnancy occur, it rises to the standard it attains after their entire cessation, namely, 8·4 grammes.
15	8·7	12–38	6·4	
16	10·8	38–50	8·4	
18–20	11·4	50–60	7·3	
20–30	12·2	60–80	6·8	
30–40	12·2	82	6·0	
40–60	10·1			
60–80	9·2			
102	5·9			

These numbers express the averages,—the maximum amount being often considerably greater. In a young man of athletic system, and sound constitution, the quantity of carbonic acid exhaled in an hour was 14·1 grammes; in a man of 60, equally vigorous for his age, 13·6 grammes; and in one of 63, 12·4 grammes. An old man, of 92, of a remarkable degree of energy, and who had possessed unusual vigour in his youth, was found to exhale 8·8 grammes per hour; whilst the same amount appeared to be the ordinary standard in a man of 45; who, unlike the last, had a feeble system, although in equally good health. How far these variations were connected with differences in the capacity of the chest, and with the number of the respiratory movements, MM. Andral and Gavarret proposed to investigate subsequently. This they have not done.

The following table, by Dr. John Reid,[1] of the quantity of carbonic acid gas in 100 parts of the expired air estimated by volume gives the result obtained by recent experimenters.

	Average.	Maximum.	Minimum.	Difference between Maximum and Minimum.
Prout - - - -	3·45	4·10	3·30	·80
Coathupe - - -	4·02	7·98	1·91	6.07
Brunner and Valentin -	4·380	5·495	3.299	2·196
Vierordt - - -	4·334	6·220	3·358	2.86
Thomson - - -	4·16	7·16	1·71	5.45

It has been a question amongst physiologists, whether the quantity of carbonic acid given out is equal in bulk to the oxygen taken in. In Dr. Priestley's experiments,[2] the latter had the preponderance. Menzies and Crawford found them to be equal. MM. Lavoisier and Séguin supposed the oxygen, consumed in the twenty-four hours, to be 15661·66 grains; whilst the oxygen, required for the formation of the carbonic acid given out, was no more than 12,924 grains; and Sir Humphry Davy found the oxygen consumed in the same time to be 15,337 grains, whilst the carbonic acid produced was 17811·36 grains; which would contain 12824·18 grains of oxygen. The experiments of Messrs. Allen and Pepys seem, however, to show that the oxygen which disappears is replaced by an equal volume of carbonic acid; and hence it was supposed that the whole of it must have been employed in the formation of this acid. They, consequently, accord with Menzies and Crawford; and the view is embraced by Dalton, Prout, Ellis, Henry, and other distinguished individuals. On the other hand, the view of those, who consider that the quantity of carbonic acid produced is less than that of the oxygen which has disappeared, is embraced by Dr. Thomson, and by MM. Dulong and Despretz. In the carnivorous animal, they found the difference as much as one-third; in the herbivorous, on the average, only one-tenth. The experiments of M. Edwards have shown, that here, also, the discordance has not depended so much upon the different methods and skill of the operators, as upon

[1] Art. Respiration, Cyclopædia of Anat. and Physiol., Pt. xxxii. p. 345, Lond., Aug., 1848.
[2] Experiments, &c., on Different Kinds of Air, vol. iii., 3d edit., Lond., 1781.

a variation in the results arising from other causes; and he concludes, that the proportion of oxygen consumed, to that employed in the production of carbonic acid varies from more than one-third of the volume of carbonic acid, to almost nothing; that the variation depends upon the particular animal species subjected to experiment, its age, or some peculiarity of constitution, and that it differs considerably in the same individual at different times.

According to the law of diffusion of gases, the carbonic acid given off from the blood will, of itself, independently of the movements of respiration, have a tendency to quit the lungs by diffusing itself in the external air in which it is in less proportion; and the oxygen of the bronchial tubes and external air will have a tendency to pass towards the air-cells in which its proportion is less than in the air of the tubes and the external air. Were this not the case, the air in the air-cells would be highly charged with carbonic acid, and could not fail to act injuriously, inasmuch as the respiratory movements, even when aided by the resiliency of the pulmonary tissue, can never empty the air-cells; and hence there is always—as has been shown—a quantity of *reserve* and *residual* air in the cells.[1]

Interesting experiments by Valentin[2] and Brunner, made on a large scale, seemed to demonstrate, that the chemical changes in respiration are a good deal owing to the simple diffusion of gases taking place between those of the atmosphere and of the blood. The volumes of oxygen absorbed and of carbonic acid exhaled from the blood may be, according to them, determined by the established laws of the diffusion of gases, so that, for one volume of carbonic acid exhaled, 1·17421 volume of oxygen is absorbed,—these numbers representing the proportionate diffusion-volumes of the two gases, calculated according to the law that they are inversely as the square roots of their specific gravities,—or, according to weight, one part of carbonic acid to 0·85163 of oxygen. One part by weight of carbonic acid contains 0·72727 of oxygen; consequently for each part of carbonic acid discharged in respiration, there is an excess of 0.12436 of oxygen, which is disposed of otherwise than in forming the carbonic acid thrown off from the lungs,—or, by volumes, for each one of carbonic acid there is an excess of 0·17421 of oxygen. Hence if it be known how much carbonic acid has been exhaled from the lungs in a given time, we can calculate the amount of oxygen absorbed in the same time. Valentin and Brunner satisfied themselves, that in a medium temperature and atmospheric pressure, each of them, on an average of six experiments, breathed 562·929 *litres* of air in the hour, and, in the same time, expired 635·8565 grains of carbonic acid, containing 173·414 grains of carbon. From this and their respective diffusion-volumes, the hourly consumption of oxygen was calculated at 541·5 grains;—the results obtained by these gentlemen according greatly with those of MM. Andral and Gavarret.

More recently, a series of apparently carefully conducted experi-

[1] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 131.
[2] Lehrbuch der Physiologie des Menschen, i. 547.

ments in regard to the changes produced in the air by respiration has been performed by MM. Regnault and Reiset.[1] The following are the results of one on a young dog, which was confined in an appropriate apparatus for twenty-four hours and a half.

Oxygen consumed,	182·288	grammes.
Carbonic acid produced,	185·961	"
Oxygen contained in the carbonic acid,	135·244	"
Nitrogen given off,	0·1820	"

Representing the quantity of oxygen consumed at 100, the results would be as follows:—

Oxygen consumed,	100
Oxygen in the carbonic acid,	74·191
Oxygen otherwise disposed of,	25·809
Nitrogen disengaged,	0·0549
Average quantity of oxygen consumed in an hour,	7·44

These experiments are not confirmatory, however, of the views of Valentin and Brunner, in regard to the exchanged oxygen and carbonic acid in respiration, being in the proportion to each other as their diffusion-volumes. Fresh observations are, indeed, needed on this subject. In the meantime it has been well remarked by Messrs. Kirkes and Paget,[2] that the conditions of the gases, engaged in respiration, are not those in which the law of diffusion would exactly hold. The law requires, that both gases should be free and under equal pressure; whilst in the actual case, the gas in the blood is dissolved under pressure, and separated by a membrane from that with which it has to be diffused.

In their experiments on animals, MM. Regnault and Reiset found that the nature of the diet influences the relative amount of oxygen absorbed, and of carbonic acid given out. When animals were fed on flesh, they absorbed much more oxygen in proportion. In the case of a dog, confined exclusively to this kind of aliment, the proportion of oxygen absorbed to 100 parts of carbonic acid exhaled was 134·3, much more than that which the law of diffusion of gases would indicate; whilst in that of a rabbit, fed wholly on vegetable food, the proportion was as 100 to 109·34, or less. The difference between the relative proportions of surplus oxygen in the same animal, under these different circumstances, was as high as 62 to 104. The same experimenters found that, when an animal was kept fasting, the relation between the quantity of oxygen absorbed, and of carbonic acid exhaled, is nearly the same as when it is fed on flesh;—"the reason evidently being," observes a recent writer,[3] "that in the former case the animal's respiration is kept up at the expense of the constituents of its own body, which correspond with animal food in their composition." It must be borne in mind, however, that in such circumstances the fat would probably be most largely taken up; and it corresponds in composition with vegetable food.

It would appear, then, that the whole of the oxygen, which respira-

[1] Comptes Rendus, Paris, 1848. [2] Op. cit., p. 137.
[3] Carpenter's Principles of Physiology, 4th Amer. edit., p. 572, Philad., 1850.

tion abstracts from the air, is by no means accounted for by the quantity of carbonic acid formed; and that, consequently, a portion of it disappears altogether. It has been supposed by some, that a part of the watery vapour, given off during expiration is occasioned by the union of a portion of the oxygen of the air with hydrogen from the blood in the lungs; but the view is conjectural. This subject, with the quantity of vapour combined with the expired air, will be a matter of inquiry under the head of SECRETION.[1]

The air likewise loses, during inspiration, certain foreign matters diffused in it. In this way, it has been attempted to convey medicines into the system. If air, charged with odorous particles,—as with those of turpentine,—be breathed for a short time, their presence in the urine can be detected; and it is probably in this manner, that miasmata produce their effects on the frame. Anæsthetic agents act in the same manner; and all pass immediately through the coats of the pulmonary veins by imbibition, and, in this way, speedily affect the system. The changes, produced in the air during respiration, are easily shown, by placing an animal under a bell-glass, until it dies. On examining the air, it will be found to have lost a portion of its oxygen and nitrogen, and to contain carbonic acid and aqueous vapour. The expired air has always, even in greatly varying temperatures of the atmosphere, a temperature of from 97°·25 to 99°·5 Fahr.,—most commonly the latter.

Let us now inquire whether the changes produced in the respired air be connected with those effected on the blood in the lungs. In its progress through the lungs, this fluid has been changed from *venous* into *arterial*. It has become of a florid red colour; of a stronger odour; of a higher temperature by from one to four degrees, according to some,[2] but others have perceived no difference, whilst others, again, have found it of lower temperature;[3] of less specific gravity, in the ratio of 1053 to 1050 on the average, according to Dr. John Davy;[4] and it coagulates more speedily, according to most observers; but Mr. Thackrah[5] observed the contrary. That this conversion is owing to the contact of air in the lungs we have many proofs. Lower[6] was one of the first, who clearly pointed out, that the change of colour occurs in the capillaries of the lungs. Prior to his time, the most confused notions had prevailed on the subject, and the most visionary hypotheses been indulged. On opening the thorax of a living animal, he observed the precise point of the circulation at which the change of colour takes place; and showed, that it is not in the heart, since the blood, when it leaves the right ven-

[1] See on the whole of this subject, Dr. John Reid, art. Respiration, Cyclop. of Anat. and Physiol., pt. xxxii. p. 346, Lond., Aug., 1848; and Vierordt, art. Respiration, Wagner's Handwörterbuch der Physiologie, 12te Lieferung, s. 828, Braunschweig, 1845.

[2] Magendie, Précis de Physiologie, ii. 343; Dr. J. Davy, in Philos. Transact. for 1814; Metcalfe on Caloric, ii. 548, Lond., 1843; and Becquerel and Breschet, Annales des Sciences Naturelles, 2de série, vii. 94, Paris, 1837.

[3] Wagner's Elements of Physiology, by R. Willis, § 180, Lond., 1842; and Simon's Animal Chemistry, vol. i. p. 193, Lond., 1845.

[4] Physiological and Anatomical Researches, American Med. Library edit., p. 16, Philad., 1840.

[5] Inquiry into the Nature and Properties of the Blood, p. 42, Lond., 1819.

[6] Tractatus de Corde, &c., c. iii., Amstelod., 1761.

tricle, continues to be purple. He then kept the lungs artificially distended, first with a regular supply of fresh air, and afterwards with the same portion of air without renewing it. In the former case, the blood experienced the usual change of colour. In the latter, it was returned to the left side of the heart unaltered.

Experiments, more or less resembling those of Lower, have been performed by Goodwyn,[1] Cigna, Bichat,[2] Wilson Philip, and numerous others, and with similar results.

The direct experiments of Dr. Priestley[3] more clearly showed, that the change effected on the blood was to be ascribed to the air. He found, that a clot of venous blood, confined in a small quantity of air, assumed a scarlet colour, and that the air experienced the same change as from respiration. He afterwards examined the effects produced on the blood by the gaseous elements of the atmosphere separately, as well as by the other gaseous fluids that had been discovered in his time. The clot was reddened more rapidly by oxygen than by the air of the atmosphere, whilst it was reduced to a dark purple by nitrogen, hydrogen, and carbonic acid.

Since Dr. Priestley's time, the effect of different gases on the colour of venous blood has been investigated by numerous observers. The following is the result of their observations, as given by M. Thénard.[4] It must be remarked, however, that all the experiments were made on blood out of the body; and it by no means follows, that precisely the same changes would be accomplished if it were circulating in the vessels.

Gas.	Colour.	Remarks.
Oxygen	Rose red.	The blood employed had been beaten, and, consequently, deprived of its fibrin.
Atmospheric air	Do.	
Ammonia	Cherry red.	
Gaseous oxide of carbon	Slightly violet red.	
Deutoxide of azote	Do.	
Carburetted hydrogen	Do.	
Azote	Brown red.	
Carbonic acid	Do.	
Hydrogen	Do.[5]	
Protoxide of azote	Do.	
Arseniuretted hydrogen Sulphuretted hydrogen	Deep violet, passing gradually to a greenish brown.	
Chlorohydric acid gas	Maroon brown.	These three gases coagulated the blood at the same time.
Sulphurous acid gas	Black brown.	
Chlorine	Blackish brown, passing by degrees to a yellowish white.	

It is sufficiently manifest, then, from the disappearance of a part of the oxygen from the inspired air, and from the effects of that gas on

[1] The Connexion of Life with Respiration, &c., Lond., 1788.
[2] Recherches Physiol. sur la Vie et la Mort, 3ème édit., p. 238, Paris, 1805.
[3] Experiments, &c., on Different Kinds of Air, &c., Lond., 1781.
[4] Traité de Chimie, &c., 5e édit., Paris, 1827.
[5] Müller says he agitated blood with hydrogen, but could perceive no change of colour. Handbuch, u. s. w., Baly's translation, p. 322, Lond., 1838.

venous blood out of the body, that it plays an essential part in the function of sanguification. But we have seen, that the expired air contains an unusual proportion of carbonic acid. Hence carbon, either in its simple state or united with oxygen, must have been given off from the blood in the vessels of the lungs.

To account for these changes on chemical principles has been a great object with chemical physiologists at all times. At an early period, the conversion of venous into arterial blood was supposed to be a kind of combustion; and, according to the Stahlian notion of combustion then prevalent, it was presumed to consist in the disengagement of phlogiston; in other words, the abstraction or addition of a portion of phlogiston made the blood, it was conceived, arterial or venous; and its removal was looked upon as the principal use of respiration. This hypothesis was modified by Lavoisier, who proposed one of the chemical views to be now mentioned.

Two chief chemical theories have been framed to explain the mode in which carbon is given off. The first is that of Black,[1] Priestley,[2] Lavoisier,[3] Crawford;[4] and others;[5]—that the oxygen of the inspired air attracts carbon from venous blood, and the carbonic acid is generated by their union. The second, which has been supported by La Grange,[6] Hassenfratz,[7] Edwards,[8] Müller,[9] Bischoff, Magnus and others, —that the carbonic acid is generated in the course of the circulation, and is given off from the venous blood in the lungs, whilst oxygen gas is absorbed. The former of these views is still maintained by many chemical physiologists. It is conceived, that the oxygen, derived from the air unites with certain parts of the venous blood,—the carbon and hydrogen,—owing to which union, carbonic acid and water are found in the expired air; the venous blood, thus depurated of its carbon and hydrogen, becomes arterialized; and, in consequence of these various combinations, heat enough is disengaged to keep the body always at the due temperature. According to this theory, respiration is assimilated to combustion. The resemblance, indeed, between the two processes is striking. The presence of air is absolutely necessary for respiration; in every variety the air is robbed of a portion of its oxygen; hence a fresh supply is continually needed; and respiration is always arrested before the whole of the oxygen of the air is exhausted, and this partly on account of the residuary nitrogen and carbonic acid gas given off during expiration. Lastly, it can be continued much longer when an animal is confined in pure oxygen than in atmospheric air. All these circumstances likewise occur in combustion. Every kind requires the presence of air. A part of the oxygen is consumed; and, unless the air is renewed, combustion is impossible. It is arrested, too, before the whole of the oxygen is consumed, owing to the residuary

[1] Lectures on the Elements of Chemistry, by Robison, ii. 87, Edinb., 1803.
[2] Philosoph. Transact. for 1776, p. 147.
[3] Mém. de l'Acad. des Sciences, pour 1777, p. 185.
[4] On Animal Heat, 2d edit., Lond., 1788.
[5] Metcalfe, op. cit.
[6] Annales de Chimie, ix. 269.
[7] Ibid., ix. 265.
[8] De l'Influence des Agens Physiques, &c., p. 411, Paris, 1823; or Hodgkin and Fisher's translation.
[9] Physiology, by Baly, p. 537.

nitrogen, and carbonic acid formed; and it can be longer maintained in pure oxygen than in atmospheric air. Moreover, when air has been respired, it becomes unfit for combustion. Again, the oxygen of the air, in which combustion is taking place, combines with the carbon and hydrogen of the burning body; hence the formation of carbonic acid and water; and, as in this combination, the oxygen passes from the state of a rare gas, or one containing a considerable quantity of caloric between its molecules, to that of a much denser, and even of a liquid, the whole of the caloric, which the oxygen contained in its former state, can no longer be held in the latter, and is accordingly disengaged; hence the increased temperature. In like manner, in respiration, the oxygen of the inspired air, it is conceived, combines with the carbon and hydrogen of the venous blood, giving rise to the formation of carbonic acid and water; and, as in these combinations, the oxygen passes from the state of a rare to that of a denser gas, or of a liquid, there is a considerable disengagement of caloric, which becomes the source of the high temperature maintained by the human body. M. Thénard[1] admits a modification of this view,—sanguification being owing, he conceives, to the combustion of the carbonaceous parts of the venous blood, and probably of its colouring matter, by the oxygen of the air.

This chemical theory, which originated chiefly with Lavoisier, and La Place and Séguin, was adopted by many physiologists with but little modification. Mr. Ellis, indeed, imagined, that the carbon is separated from the venous blood by a secretory process; and that then, coming into direct contact with oxygen, it is converted into carbonic acid. The circumstance that led him to this opinion was his disbelief in the possibility of oxygen being able to act upon the blood through the animal membrane or coat of the vessel in which it is confined. It is obvious, however, that to reach the blood circulating in the lungs, the oxygen must, in all cases, pass through the coats of the pulmonary vessels. These coats, indeed, offer little or no obstacle, and, consequently, there is no necessity for the vital or secretory action suggested by Mr. Ellis. Besides, Priestley and Hassenfratz exposed venous blood to atmospheric air and oxygen in a bladder, and in all cases, the parts of the blood, in contact with the gases, became of a florid colour. The experiments of Drs. Faust, Mitchell, and others (vol. i. p. 65), are, in this respect, pregnant with interest. They prove the great facility with which the tissues are penetrated by gases, and confirm the facts developed by the experiments of Priestley, Hassenfratz, and others.

The second theory,—that the carbonic acid is generated in the course of the circulation,—was proposed by M. La Grange, in consequence of the objection he saw to the former hypothesis—that the lung ought to be consumed by the perpetual disengagement of caloric within it; or, if not so, that its temperature ought to be much superior to that of other parts. He accordingly suggested, that, in the lungs, the oxygen is simply absorbed, passes into the venous blood, circulates with it, and unites, in its course, with the carbon and hydrogen, so as to form carbonic acid and water, which circulate with the blood, and are finally exhaled from the lungs.

[1] Traité de Chimie, edit. citat.

The ingenious and apparently accurate experiments of M. Edwards[1] proved convincingly, not only that oxygen is absorbed by the pulmonary vessels, but that carbonic acid is exhaled from them. When he confined a small animal in a large quantity of air, and continued the experiment sufficiently long, he found, that the rate of absorption was greater at the commencement than towards the termination of the experiment; and that, at the former period, there was an excess of oxygen, and at the latter an excess of carbonic acid. This proved to him, that the diminution was dependent upon the absorption of oxygen, not of carbonic acid. His experiments, in proof of the exhalation of carbonic acid, ready formed, by the lungs, are decisive. Spallanzani had asserted, that when certain of the lower animals are confined in gases containing no oxygen, the production of carbonic acid is uninterrupted. Upon the strength of this assertion, M. Edwards confined hogs in pure hydrogen for a length of time. The result indicated, that carbonic acid was produced, and in such quantity, that it could not have been derived from the residuary air in the lungs; as in some cases it was equal to the bulk of the animal. The same results, although to a less degree, were obtained with fishes and snails,—the animals on which Spallanzani's observations were made. The experiments of Edwards were extended to the mammalia. Kittens, two or three days old, were immersed in hydrogen; they remained in this situation for nearly twenty minutes without dying, and on examining the air of the vessel after death, it was found, that they had given off a quantity of carbonic acid greater than could possibly have been contained in their lungs at the commencement of the experiment. The conclusion of Dr. Edwards, from his various experiments, is, "that the carbonic acid expired is an exhalation proceeding wholly or in part from the carbonic acid contained in the mass of blood." Several experiments were subsequently made by M. Collard de Martigny,[2] who substituted nitrogen for hydrogen; and, in all cases, carbonic acid gas was given out in considerable quantity. These and other experiments would seem, then, to show, that in the lungs, carbonic acid is exhaled, and oxygen and nitrogen are absorbed. They would also seem to prove the existence of carbonic acid in venous blood, respecting which so much dissidence has existed amongst chemists.

Allusion has already been made to the fact, that gelatin is not met with in the blood, and to the idea of Dr. Prout,[3] that its formation from albumen must be a *reducing* process. This process he considers to be one great source of the carbonic acid that exists in venous blood. Gelatin contains three or four per cent. less carbon than albumen; it enters into the structure of every part of the animal frame, and especially of the skin; the skin, indeed, contains little else than it. He considers it, therefore, most probable, that a large part of the carbonic acid of venous blood is formed in the skin, and analogous textures. "Indeed," he adds, "we know that the skin of many animals gives off carbonic acid, and absorbs oxygen;—in other words, performs all the offices of the lungs;—a function of the skin perfectly intelligible, on

[1] Op. citat., p. 437, and Messrs. Allen and Pepys, in Philos. Transactions for 1829.
[2] Journal de Physiologie, x. 111.
[3] Bridgewater Treatise, Amer. edit., p. 280, Philad., 1834.

the supposition, that near the surface of the body, the albuminous portions of the blood are always converted into gelatin." Gmelin and Tiedemann, Mitscherlich,[1] and Stromeyer,[2] affirm, on the strength of experiments, that the blood does not contain free carbonic acid, but that it holds a certain quantity in a state of combination, which is set free in the lungs, and commingles with the expired air. The views of Gmelin and Tiedemann, and Mitscherlich on this subject are as follows. It may be laid down as a truth, that the greater part, if not all, of the properties of secreted fluids are not dependent upon any act of the secreting organs, but are derived from the blood, which again, must either owe them to the food, or to changes effected on it within the body. These changes are probably accomplished, in part, during the process of digestion, but are doubtless mainly effected in the lungs by the contact of the blood with the air. Now, most of the animal fluids, when exposed to the air, generate, by the absorption of oxygen, acetic or lactic acid, and this is aided by an elevated temperature, like that of the lungs. In their theory of respiration, the nitrogen of the inspired air is but sparingly absorbed,—by far the greater proportion remaining in the air-cells. The oxygen, on the other hand, penetrates the membranes freely; mingles with the blood; combines partly with the carbon and hydrogen of that fluid, and generates carbonic acid and water, which are thrown off with the expired air; the remainder combines with the organic particles of the blood, forming new compounds, of which the acetic and lactic acids are two; these unite with the carbonated alkaline salts of the blood, and set free the carbonic acid, so that it can be thrown off by the lungs. The acetate of soda—thus formed during the passage of the blood through the lungs—is deprived of its acetic acid by the several secretions, especially by those of the skin and kidneys, and the soda again combines with the carbonic acid, formed during the circulation of the blood through the body, by the decomposition of its organic elements. Carbonate of soda is thus regenerated, and conveyed to the lungs, to be again decomposed by the fresh formation of acids in those organs. Almost the same view is entertained by MM. Dumas and Boussingault, and it is esteemed by Professor Graham[3] to be highly probable. Another view, in many respects similar, is held by Professor Arnold.[4] As it is more than probable, he remarks, that the carbonic acid occurs in the venous blood, united with some substance from which it is separated with greater or less rapidity by the contact of atmospheric air; and as, further, the carbonate of protoxide of iron greedily withdraws oxygen from the atmosphere, at the same time parting with its carbonic acid and becoming changed into a peroxide, it may be reasonably supposed, that the carbonic acid of venous blood is united with the iron of the red colouring matter, and is set free during the act of respiration, by the reciprocal action of the blood and air. The protoxide, by absorption of oxygen, becomes a peroxide, which, during the circulation of the blood through the capillaries, again parts with its oxygen.

[1] Tiedemann und Treviranus, Zeitschrift für Physiol., B. v. H. i.
[2] Schweigger's Journal für Chimie, u. s. w., lxiv. 105.
[3] Elements of Chemistry, Amer. edit., by Dr. Bridges, p. 687, Philad., 1843.
[4] Lehrbuch der Physiologie des Menschen, Zürich, 1836-7.

Carbon is at the same time eliminated from the blood, and unites with the liberated oxygen to form carbonic acid, which is thrown out by the lungs, whilst oxygen is again absorbed. This is the view embraced by Liebig,[1] who has affirmed, that the amount of iron present in the blood, if in the state of protoxide, is sufficient to furnish the means of transporting twice as much carbonic acid as can possibly be formed by the oxygen absorbed in the lungs.

MM. Chaussier and Adelon,[2] again, regard the whole process of hæmatosis to be essentially *organic* and *vital*. They are of opinion, that an action of selection and elaboration is exerted both as regards the reception of oxygen and the elimination of carbonic acid. But their arguments on this point are unsatisfactory, and are negatived by the facility with which oxygen can be imbibed, and carbonic acid transudes through animal membranes. In their view, the whole process is effected in the lungs, as soon as the air comes in contact with the vessels containing venous blood. Imbibition of oxygen they look upon as a case of ordinary absorption; transudation of carbonic acid as one of exhalation; both of which they conceive to be, in all cases, *vital* actions, and not to be likened to any physical or chemical process.

Admitting that oxygen and a portion of nitrogen absolutely enter the pulmonary vessels, of which we have direct proof, are they, it has been asked, separated from the air in the air-cells, and then absorbed; or does the air enter undecomposed into the vessels, and then furnish the proportion of each of its constituents needed by the wants of the system,—the excess being rejected? Could it be shown, that such a decomposition is actually effected at the point of contact between the pulmonary vessels and the air in the lungs, it would seem, at first, to prove the notion of Mr. Ellis,[3] and of Chaussier and Adelon, that a vital action of selection is exerted; but the knowledge we have attained concerning the transmission of gases through animal membranes would suggest another explanation. The rate of transmission of carbonic acid is greater than that of oxygen; of oxygen greater than that of nitrogen (see vol. i. p. 68). We can hence understand, that more oxygen than nitrogen may pass through the coats of the pulmonary bloodvessels, and can comprehend the facility with which the carbonic acid, formed in the course of the circulation, may permeate the same vessels, and mix with the air in the lungs. Sir Humphry Davy is of opinion, that the whole of the air is absorbed, and that the surplus quantity of each of the constituents is subsequently discharged. In favour of this view, he remarks that air has the power of acting upon the blood through a stratum of serum, and he thinks that the undecomposed air must be absorbed before it can arrive at the blood in the vessels. It is probable, however, from the different penetrating powers of the gases—oxygen and nitrogen, that the proportion of those constituents cannot be the same in the interior as at the exterior of the pulmonary vessels. Pro-

[1] Animal Chemistry, Webster's Amer. edit., p. 261, Cambridge, 1843.
[2] Physiologie de l'Homme, edit. cit., iii. 254.
[3] An Enquiry into the Changes induced on Atmospheric Air, &c., Edinb., 1807; and Further Enquiries, Edinb., 1816.

fessor Muller,[1] however, accords with Sir Humphry, and supposes that the air, on entering the lungs, is decomposed in consequence of the affinity of oxygen for the red particles of the blood; carbonic acid being formed, which is exhaled in the gaseous form, along with the greater part of the nitrogen.[2]

It has been remarked, that when oxygen is applied to venous blood out of the body, the latter assumes a florid colour. On what part of the blood, then, does the oxygen act? Doubtless, upon the red corpuscles. Facts, hereafter stated in the description of venous blood, have appeared to some to show that these corpuscles are devoid of colour, whilst they exist in chyle and lymph; but in the lungs, the contact of air changes them to a florid red. The coloration of the blood is, consequently, effected in the lungs; but whether this change be of any importance in hæmatosis is doubtful. In many animals, the red colour does not exist; and, in all, it can perhaps only be esteemed an evidence, that the other important changes have been accomplished in those organs. Of late, the opinion has been revived, that the oxygen of the air acts upon the iron, which Engelhart and Rose[3] had detected in the colouring matter,—but how we are not instructed. It has been asserted, that if the iron be separated, the rest of the colouring matter, which is of a venous red colour, loses the property of becoming scarlet by the contact of oxygen; but this, again, has been denied.

Another view of arterialization has been advanced by Dr. Stevens.[4] According to him, the colouring matter is naturally very dark; is rendered still darker by acids, and acquires a florid hue from the addition of chloride of sodium, and from the neutral salts of the alkalies generally. The colour of arterial blood is ascribed by him to hematosin reddened by the salts contained in the serum; the characters of venous blood to the presumed presence of carbonic acid, which, like other acids, darkens hematosin; and the conversion of venous into arterial blood to the influence of the saline matter in the serum being restored by the separation of carbonic acid. If we take a firm clot of venous blood, cut off a thin slice, and soak it for an hour or two in repeatedly renewed portions of distilled water; in proportion as the serum is washed away, the colour of the clot deepens; and, when scarcely any serum remains, the colour, by reflected light, is quite black. In this state, it may be exposed to the atmosphere, or a current of air may be blown upon it without any change of tint whatever; whence it would follow, that when a clot of venous blood, moistened with serum, is made florid by the air, the presence of serum is essential to the phenomenon. The serum is believed, by Dr. Stevens, to contribute to this change by means of its saline matter; for when a dark clot of blood, which oxygen fails to redden, is immersed in a pure solution of salt, it quickly acquires

[1] Handbuch, u. s. w., Baly's translation, p. 334, Lond., 1838.

[2] See, on this subject, Dr. John Reid, art. Respiration, Cyclop. of Anat. and Physiol., Pt. xxxii. p. 365, Lond., Aug., 1848.

[3] Edinb. Med. and Surg. Journal for Jan., 1827.

[4] Observations on the Healthy and Diseased Properties of the Blood, Lond., 1832; and Proceedings of the Royal Society for 1834–5, p. 334.

the crimson tint of arterial blood; and loses it again when the salt is abstracted by soaking in distilled water. The facts, detailed by Dr. Stevens, were confirmed by Mr. Prater,[1] and by Dr. Turner,[2] of the London University. The latter gentleman, assisted by Professor Quain, of the same institution, performed the following satisfactory experiment. He collected some perfectly florid blood from the femoral artery of a dog; and on the following day, when a firm coagulum had formed, several thin slices were cut from the clot with a sharp penknife, and the serum was removed from them by distilled water, which had just before been briskly boiled, and allowed to cool in a well-corked bottle. The water was gently poured on these slices, so that while the serum was dissolving, as little as possible of the colouring matter should be lost. After the water had been poured off, and renewed four or five times, occupying in all about an hour, the moist slices were placed in a saucer at the side of the original clot, and both portions were shown to several medical friends, all of whom unhesitatingly pronounced the unwashed clot to have the perfect appearance of arterial blood, and the washed slices to be as perfectly venous. On restoring one of the slices to the serum it shortly recovered its florid colour; and another slice, placed in a solution of bicarbonate of soda, instantly acquired a similar hue;—yet, as we have seen, carbonate of soda is considered by Messrs. Gmelin, Tiedemann, and Mitscherlich, to exist in venous or black blood!

In brightening, in this way, a dark clot by a solution of salt or a bicarbonate, Dr. Turner found the colour to be often still more florid than that of arterial blood; but the colours were exactly alike when the salt was duly diluted. Dr. Turner remarks, that he is at a loss to draw any other inference from this experiment, than that the florid colour of arterial blood is not due to oxygen; but, as Dr. Stevens suggests, to the saline matter of the serum. The arterial blood, which was used, had been duly oxygenized within the body of the animal, and should not in that state have lost its tint by the mere removal of its serum; and he adds,—the change from venous to arterial blood appears, contrary to the received doctrine, to consist of two parts essentially distinct; one a chemical change, essential to life, accompanied by absorption of oxygen, and evolution of carbonic acid; the other dependant on the saline matter of the blood, which gives a florid tint to the colouring matter after it has been modified by the action of oxygen. "Such," says Dr. Turner, "appears to be a fair inference from the facts above stated; but being drawn from very limited observation, it is offered with diffidence, and requires to be confirmed or modified by future researches." But we are perhaps scarcely justified in inferring, from the experiments of Stevens, Turner, and others, more than the fact, that a florid hue is communicated to blood by sea-salt, and by the neutral salts of the alkalies in general, and indeed by admixture with sugars; whilst acids render it still darker. The precise changes that occur during the arterialization of the blood in the lungs are still unknown;

[1] Experim. Inquiries in Chemical Physiology, Part i., on the Blood, Lond., 1832.
[2] Elements of Chemistry, 5th edit., by Dr. Bache, p. 609, Philad., 1835.

and if we rely on the recent experiments of Gmelin, Tiedemann, and Mitscherlich, venous blood cannot owe its colour to free carbonic acid, because none is to be met with in it; whilst the presence of the carbonates of alkalies ought to communicate the florid hue to it.

Since Dr. Stevens first published his views, the subject has been farther investigated by Dr. William Gregory, and Mr. Irvine. They introduced portions of clot, freed by washing from serum, into vessels containing pure hydrogen, nitrogen, and carbonic acid, placed over mercury. As soon as the strong saline solution came in contact with them, the colour of the clot, in all the true gases, changed from black to bright red; and the same change was found to take place in the Torricellian vacuum. On repeating these experiments with the serum of blood, and a solution of salt in water of equal strength with the serum, no change took place until atmospheric air, or oxygen gas, was admitted. Whence it appears—as properly inferred by the late Mr. Egerton A. Jennings, who published an interesting "Report on the Chemistry of the Blood as Illustrative of Pathology,"[1]—that though saline matter may be necessary to effect the change of colour of venous to that of arterial blood, with so dilute a saline solution as that which exists in serum, the presence of oxygen is likewise necessary. Dr. Davy[2] dissents, however, from these conclusions, and is disposed to infer, from all the facts with which he is acquainted, that the colour of the blood, whether venous or arterial,—that is, dark or florid,—is independent of the saline matter in the serum, considered in relation to agency; and that, according to the commonly received view, oxygen is the cause of the bright hue of the arterial fluid, and its consumption and conversion into carbonic acid the cause of the dark hue of the venous,—the saline matter being negative in regard to colour; and its chief use, in his opinion, being "to preserve the red globules from injury, prevent the solution of their colouring matter, retain their forms unchanged, and to bear them in their course through the circulation."

An idea has been entertained, that the change from arterial to venous blood, and conversely, as regards colour, is dependent in a great measure on a difference in the shape of the blood corpuscles; and is therefore owing rather to physical than to chemical changes in them. Such is the opinion of Kaltenbrunner, Schultz, Reuter, Gulliver, Harless, Kirkes and Paget,[3] Nasse, Mulder, and others. It is of course opposed to that of Liebig, already stated. Mulder[4] explains the difference between the colour of arterial and venous blood as follows. Two oxides of protein are formed in the act of respiration, which have a strong plastic tendency, and solidify around each corpuscle, making the capsule thicker, and better qualified to reflect light. Each corpuscle of arterialized blood is then, in reality, invested with a complete envelope

[1] Transactions of the Provincial Medical and Surgical Association, vol. iii., Worcester and London, 1835.

[2] Researches, Physiological and Anatomical, Dunglison's Amer. Med. Lib. edit., p. 96, Philad., 1840.

[3] Manual of Physiology, Amer. edit., p. 59, Philad., 1849.

[4] Versuch einer Allgemeinen Physiologischen Chemie, cited by Mr. Day in Simon, Animal Chemistry, Sydenham edit., p. 193, Lond., 1845; and Chemistry of Vegetable and Animal Physiology, translated by Fromberg, p. 342, Lond. and Edinb., 1849.

of buffy coat, which gradually contracts, and speedily forms cupped or bi-concave surfaces, which are favourable to the reflection of light. On reaching the capillaries, the coating of the oxides of protein is removed, and the corpuscles, losing their opaque investment, and cupped form, no longer reflect light, and the blood assumes the venous tint. Dr. G. O. Rees,[1] however, considers this explanation to be entirely hypothetical and erroneous. He rejects the idea of a layer of plastic oxy-protein being deposited on the blood corpuscles during respiration; and instead of considering the hematosin as undergoing no change, and maintaining the same condition in arterial and venous blood, he looks upon it as the cause of the change of colour in the blood by virtue of some chemical alteration, which takes place in it, but whose nature—if there be any such alteration—remains a mystery. Recently, indeed, he has himself advanced the following ingenious theory.[2] He found by analyses, that the corpuscles of venous blood contain fatty matter in combination with phosphorus. This does not exist in arterial blood, or, at most, is met with in it in very small quantity. During respiration the oxygen of the inspired air unites with the phosphorus and fatty matter, and combustion takes place; of which the products are water and carbonic acid from the union of the oxygen with the elements of the fatty matter; and phosphoric acid from the union of the oxygen with the phosphorus. The carbonic acid and water are exhaled, and appear in the expired air; the phosphoric acid attracts the soda of the liquor sanguinis from its combination with albumen and lactic acid, and forms a tribasic phosphate of soda,—a salt, which possesses in a marked degree the property of communicating a bright colour to hematosin.

It is proper to add, that Burdach, Müller, Bruch, Marchand, Scherer, and others, have failed to detect by the microscope any difference in the external form of the corpuscles in arterial and in venous blood. Still, Dr. John Reid[3] is disposed to conclude, that the change in the blood from the venous to the arterial hue in the lungs is a physical and not a chemical action; and "that though there is pretty strong evidence in favour of the opinion, that this physical change consists in an alteration of the form of the red corpuscles, yet it is not free from doubt."

The slight diminution, if it exist, in the specific gravity of arterial blood has been considered, but we know not on what grounds, to depend on the transpiration, which takes place into the air-cells, and was formerly thought to be owing to the combustion of oxygen and hydrogen. This will engage us in another place;—as well as the changes produced in its capacity for heat, on which several ingenious speculations have been founded to account for ANIMAL TEMPERATURE. The other changes are at present inexplicable; and can only be understood by minute chemical analysis, and by an accurate comparison of the two kinds of blood,—venous and arterial. This has been carefully done by Simon, who

[1] Lond. Med. Gazette, 1844–5, p. 840, and Mulder, op. cit., p. 341.

[2] Proceedings of the Royal Society, June 3, 1847, and Lond., Edinb., and Dublin Philos. Magazine for July, 1848.

[3] Art. Respiration, Cyclop. of Anat. and Physiology, Pt. xxxii. p. 361, London, August, 1848.

infers, from his analyses, that arterial blood generally contains less solid residue than venous blood; and less fat, albumen, hematin, extractive matter, and salts; but further experiments are demanded.

The blood corpuscles of arterial blood contain less colouring matter than those of venous blood.[1]

It is manifest, from the preceding detail, that our knowledge regarding the precise changes effected on the air and the blood by respiration is by no means definite. We may, however, consider the following points established. In the first place:—the air loses a part of its oxygen and nitrogen; but this loss varies according to numerous circumstances. 2dly. It is found to have acquired carbonic acid, the quantity of which is also variable. 3dly. The bulk of the air is diminished; but the extent of this likewise differs. 4thly. The blood, when it attains the left side of the heart, has a more florid colour. 5thly. This change appears to be caused by the contact of oxygen. 6thly. The blood in the lungs gets rid of a quantity of carbonic acid. 7thly. The oxygen taken in is more than necessary for the carbonic acid formed. 8thly. The constituents of the air pass directly through the coats of the pulmonary vessels, and certain portions of each are discharged or retained, according to circumstances. 9thly. A quantity of aqueous vapour is discharged from the lungs; the expired air is indeed saturated with it. 10thly. The expired air has always a temperature at or near 99°; and, lastly, it would appear, from the facts stated elsewhere, that the red corpuscles are not the only constituent of the blood that undergoes a change in the respiratory process; and that the fibrin of venous blood most nearly resembles albumen, whilst that of arterial blood contains more oxygen, and is more highly animalized.

c. *Cutaneous Respiration, &c.*

A question has arisen, whether any absorption and exhalation of air, and conversion of blood from venous to arterial, take place in any other part of the body than the lungs. The reasons, urged in favour of the affirmative of this question, are;—that, in the lower classes of animals, the skin is manifestly the organ for the reception of air; that the mucous membrane of the lungs evidently absorbs air, and is simply a prolongation of the skin, resembling it in texture; and, lastly, that when a limited quantity of air has been placed in contact with the skin of a living animal, it has been absorbed, and found to have experienced the same changes as are effected in the lungs. Mr. Cruikshank[2] and Mr. Abernethy[3] analyzed air, in which the hand or foot had been confined for a time; and detected in it a considerable quantity of carbonic acid. Jurine, having placed his arm in a cylinder hermetically closed, found, after it had remained there two hours, that oxygen had disappeared, and 0·08 of carbonic acid had been formed. These results were confirmed by Gattoni;[4] and from experiments by Professor

[1] For various analyses of the two kinds of blood, see Simon, op. cit., p. 194.
[2] Experiments on the Insensible Perspiration, &c., Lond., 1795.
[3] Surgical and Physiological Essays, Part ii. p. 115, Lond., 1793.
[4] Dict. des Sciences Médicales, art. Peau.

Scharling, referred to before, the amount of carbon exhaled by the skin in the twenty-four hours, has been estimated at two ounces; but this is probably beyond the real amount. On the other hand, Drs. Priestley,[1] Klapp,[2] and Gordon[3] could never perceive the least change in the air under such circumstances. Perhaps in these, as in all cases where the respectability of testimony is equal, the positive ought to be adopted rather than the negative. It is probable, however, that absorption is effected with difficulty; and that the cuticle, as we have elsewhere shown, is placed on the outer surface to obviate the bad effects that would be induced by heterogeneous gaseous, miasmatic, or other absorption. We have seen that some of the deleterious gases, as sulphuretted hydrogen, are most powerfully penetrant, and, if they could enter the surface of the body with readiness, unfortunate results might supervene. In those parts where the cuticle is extremely delicate, as in the lips, some conversion of venous into arterial blood may be effected, and this may be a great cause of their florid colour.

According to this view, the arterialization of the blood occurs in the lungs chiefly, owing to their formation being so admirably adapted to the purpose; and it is not effected in other parts, because their arrangement is unfavourable for such a result.

d. *Effects of the Section of certain Nerves on Respiration.*

It remains for us to inquire into the effect produced on the lungs by the cerebro-spinal nerves distributed to them,—or rather, into what is the effect of depriving the respiratory organs of their nervous influence from the brain and spinal marrow. The only encephalic nerves, distributed to them, are the pneumogastric or eighth pair of Willis, which, we have seen, are sent, as their name imports, to both the lungs and stomach. The section of these nerves early suggested itself to physiologists, but it is only in recent times that the phenomena resulting from it have been clearly comprehended. The operation appears to have been performed as long ago as the time of Rufus of Ephesus, and was afterwards repeated by Chirac, Bohn, Duverney, Vieussens, Schräder, Valsalva, Morgagni, Haller, and numerons other distinguished physiologists. It is chiefly, however, in recent times, and especially from the labours of Dupuytren, Dumas, De Blainville, Provençal, Legallois, Magendie, Breschet, Hastings, Broughton, Brodie, Wilson Philip, Longet, John Reid, and others, that the precise effects upon the respiratory and digestive functions have been appreciated.

When these nerves are divided in a living animal, on both sides at once, the animal dies more or less promptly; at times immediately after their division, but it sometimes lives for a few days;—M. Magendie says never beyond three or four. The effects produced upon the voice, by their division above the origin of the recurrents, have been referred to under another head (vol. i. p. 593). Such division, however, does not simply implicate the larynx; it necessarily affects the lungs, as well as the stomach. As regards the larynx, the same results, accord-

[1] Experiments and Observations on Different Kinds of Air, ii. 193, and v. 100, Lond., 1774.
[2] Inaugural Essay on Cuticular Absorption, p. 24, Philad., 1805.
[3] Ellis's Inquiry into the Changes of Atmospheric Air, &c., p. 355, Edinb., 1837.

ing to M. Magendie,[1] are produced by dividing the trunk of the pneumogastric above the origin of the recurrents as by the division of the recurrents themselves: the muscles, whose function it is to dilate the glottis, are paralysed; and consequently, during inspiration, no dilatation takes place; whilst the constrictors, which receive their nerves from the superior laryngeal, preserve all their action, and close the glottis, at times so completely, that the animal dies at once from suffocation. But if the division of these nerves should not induce instant death in this manner, phenomena follow, considerably alike in all cases, which go on until the death of the animal. These are the following:—respiration is, at first, difficult; the inspiratory movements are more extensive and rapid, and the animal's attention appears to be particularly directed to them; the locomotive movements are less frequent, and evidently fatigue; frequently, the animal remains entirely at rest; the formation of arterial blood is not prevented at first, but soon, on the second day, for instance, the difficulty of breathing augments, and the inspiratory efforts become gradually greater. The arterial blood has now no longer the vermilion hue proper to it. It is darker than it ought to be: its temperature falls; respiration requires the exertion of all the respiratory powers; the body gradually becomes cold, and the animal dies. On opening the chest, the air-cells, bronchi, and frequently the trachea, are found filled by a frothy fluid, which is sometimes bloody; the substance of the lung is tumid; the divisions and even the trunk of the pulmonary artery are greatly distended with dark, almost black, blood; and extensive effusions of serum and even of blood are found in the parenchyma of the lungs. Experiments have, likewise, shown that, in proportion as these phenomena appeared, the animal consumed less and less oxygen, and gave off a progressively diminishing amount of carbonic acid.

From the phenomena that occur after the section of the nerves on both sides, it would seem to follow, that the first effect is exerted upon the tissues of the lungs, which, being deprived of nervous influence from the brain, are no longer capable of exerting their ordinary tonicity and muscularity. Respiration, consequently, becomes difficult; the blood no longer circulates freely through the capillary vessels of the lungs; the consequence is, that transudation of its serous portions, and occasionally effusion of blood, owing to rupture of small vessels, takes place, filling the air-cells more or less; until, ultimately, all communication is prevented between the inspired air and the bloodvessels, and the conversion of venous into arterial blood is completely precluded. Death is then the inevitable and immediate consequence. The division of the nerve on one side affects merely the lung of the corresponding side. Life can be continued by the action of one lung only: it is, indeed, a matter of astonishment how long some individuals have lived when the lungs have been almost wholly obstructed. Every morbid anatomist has had repeated opportunities of observing, that, for a length of time prior to dissolution, in cases of pulmonary consumption, the process of respiration must have been carried on by a very small portion of lung.

[1] Précis, &c., 2de édit., ii. 355.

From his experiments on this subject, Sir Astley Cooper infers, that the pneumogastric nerve is most important;—1st, in assisting in the maintenance of the function of the lungs, by contributing to the change of venous into arterial blood; 2dly, in being necessary to the act of swallowing; and 3dly, in being essential to the digestive process. Dr. John Reid is of opinion, that the pulmonary branches would seem to be nerves concerned chiefly in transmitting to the medulla oblongata the impressions that excite respiratory movements, and are thus principally afferent nerves; but it is possible, he thinks, that they contain motor filaments also.[1]

The experiments of Dr. Wilson Philip[2] and others show, moreover,—what has been more than once inculcated,—the great similarity between the nervous and galvanic fluids. The state of dyspnœa induced by the division of the pneumogastric nerves was, in numerous cases, entirely removed by the galvanic current passed from one divided extremity to the other. The results of these experiments induced him to try galvanism in cases of asthma. By transmitting its influence from the nape of the neck to the pit of the stomach, he gave decided relief in every one of twenty-two cases; four of which occurred in private practice, and eighteen in the Worcester Infirmary.

Sir A. Cooper[3] instituted similar experiments on the phrenic nerves. As soon as they were tied, the most determined asthma was produced; breathing went on by means of the intercostal muscles; the chest was elevated to the utmost by them; and in expiration the chest was as remarkably drawn in. The animals did not live an hour; but they did not die suddenly, as they do from pressure on the carotid and vertebral arteries. The lungs appeared healthy, but the chest contained more than its natural exhalation. He also tied the great sympathetic; which produced little effect; the heart appeared to beat more quickly and feebly than usual. The animal was kept seven days, when one nerve was found ulcerated through; the other nearly so at the situation of the ligatures. On examination, no particular alteration of any organ was observed. Lastly, Sir Astley tied all three nerves on each side, the pneumogastric, phrenic, and great sympathetic: the animal lived little more than a quarter of an hour, and died of dyspnœa. From these experiments, he infers, that the sudden death, which he found to follow pressure on the sides of the neck, cannot be attributed to any injury of the nerves, but to an impediment to the due supply of blood to the great centres of nervous influence.

The nervous centre of the respiratory movements is the vesicular neurine in the upper part of the medulla oblongata. Into it the pneumogastric nerves, which appear to be the chief excitors of respiration, may be traced; and from it the different motor or efferent nerves proceed either directly or indirectly. Of these, the most important is the phrenic. The vesicular neurine of the medulla receives the impression

[1] Edinb. Med. and Surg. Journ., April, 1839; and art. Par Vagum in Cyclop. of Anat. and Physiol., Part xxvii. p. 896, March, 1846.

[2] Experimental Inquiry into the Laws of the Vital Functions, &c., 2d edit., p. 223, Lond., 1818; also, Journal of Science and Arts, viii. 72.

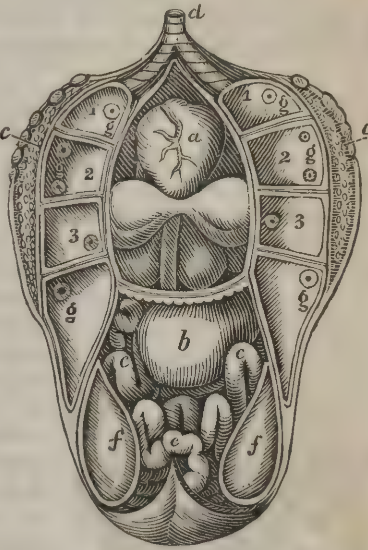
[3] Op. cit., p. 475.

of the *besoin de respirer* or necessity of breathing; and thence it is reflected along the appropriate nerves to the muscles concerned in inspiration.

e. *Respiration of Animals.*

In concluding the subject of respiration, we may briefly advert to the different modes in which the process is effected in the classes of animals, and especially in birds,—the respiratory organs of which constitute one of the most singular structures of the animal economy. The lungs themselves,—as in the marginal figure of those of the ostrich, (Fig. 273,)—are comparatively small, and adherent to the chest,—where they seem to be placed in the intervals of the ribs. They are covered by the pleura on their under surface only, so that they are, in fact, on the outside of the cavity of the chest. A great part of the thorax, as well as of the abdomen, is occupied by membranous air-cells, into which the lungs open by considerable apertures. Besides these cells, a considerable portion of the skeleton in many birds forms receptacles for air, and if we break a long bone of a bird of flight, and blow into it when the body of the animal is immersed in water, bubbles of air will escape from the bill. The object, of course, of all this arrangement is to render the body light, and thus to facilitate its motions. Hence, the largest and most numerous bony cells are found in such birds as have the highest and most rapid flight, as the eagle. The barrels of the quills are likewise hollow, and can be filled with air, or emptied at pleasure. In addition to the uses just mentioned, these air receptacles diminish the necessity for breathing so frequently in the rapid and long-continued motions of certain birds, and in the great vocal exertions of those that sing.

Fig. 273.



Thoracic and Abdominal Viscera of the Ostrich.

a. Heart, lodged in one great air-cell. *b*. The stomach. *c*. The intestines, surrounded by large air-cells. *d*. The trachea dividing into bronchi. *e*, *e*. The lungs. 1, 2, 3, *f*, *f*. Other great air-cells, communicating with other cells and with the lungs. *g*. *g*. The openings by which such communication is made.

In fishes, in the place of lungs we find *branchiæ* or *gills*, which are placed behind the head on each side, and have a movable *gill-cover*. By the throat, which is connected with the gills, the water is conveyed to, and distributed through them: in this way, the air, contained in the water, which, according to Biot, Von Humboldt[1] and Provençal, Con-

[1] Mémoires de la Société d'Arcueil, i. 252, and ii. 400.

figliachi, and Thomson,[1] is richer in oxygen than that of the atmosphere, having from 29 to 32 parts in the 100, instead of 20 or 21, comes in contact with the blood circulating through the gills. The water is afterwards discharged through the branchial openings,—*aperturæ branchiales*,—and, consequently, they do not expire along the same channel as they inspire.

Lastly, in the insect tribe,—in the white-blooded animal,—we find the function of respiration effected altogether by the surface of the body; at least, so far as regards the reception of air, which enters through apertures termed *stigmata*, the external terminations of *tracheæ* or air tubes, whose office it is to convey air to different parts of the system.

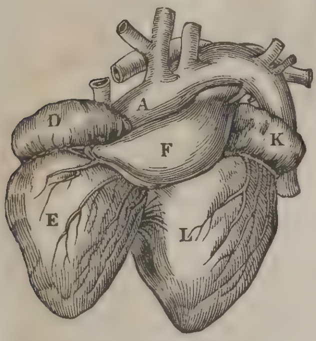
In all these cases, we find precisely the same changes effected upon the inspired air;—and especially, that oxygen and nitrogen have disappeared; and that carbonic acid of a bulk nearly equal to that of the organ is met with in the residuary air.

CHAPTER IV.

CIRCULATION.

The next function to be considered is that by which the products of the various absorptions, converted into arterial blood in the lungs, are distributed to every part of the body,—a function most important to the physiologist and the pathologist, and without a knowledge of which it is impossible for the latter to comprehend the doctrine of disease.

Fig. 274.



Heart of the Dugong.

D. Right auricle. E. Right ventricle. K. Left auricle L. Left ventricle. F. Pulmonary artery. A. Aorta.

Assuming the heart to be the great organ of the function, the circulatory fluid must set out from it, be distributed through the lungs, undergo aeration there, be sent to the opposite side of the heart, whence it is distributed to every part of the system by efferent vessels, and be returned by veins or afferent vessels to the right side, from which it set out,—thus performing a complete circuit.

The lower class of animals differ essentially, as we shall find hereafter, in their organs of circulation: whilst in some, the apparatus appears to be confounded with the digestive; in others, the blood is propelled without any great central organ; and in others, again, the heart is but a single organ. In man, and in the upper classes of animals, the heart is *double*;—consisting of two sides, or really two hearts,

[1] Dr. Thomson found that 100 cubic inches of the water of the river Clyde contained 3·113 inches of air; and that the air contained 29 per cent. of oxygen. Edinb. New Philosoph. Journal, xxi. 370, Edinb., 1836.

separated from each other by a septum. In the dugong, the two ventricles are almost entirely detached from each other.

As all the blood of the body has to be emptied into this central organ, and to be subsequently sent from it; and as its flow is continuous, two cavities are required in each heart,—the one to receive the blood, the other to propel it. The latter distinctly contracts and dilates alternately. The cavity or chamber of each heart, that receives the blood, is called *auricle*, and the vessels that transport it thither are *veins;* the cavity by which the blood is projected forwards is called *ventricle*, and the vessels, along which the blood is sent, are *arteries.* One of these hearts is entirely appropriated to the circulation of venous blood, and hence has been called *venous heart*,—also *right* or *anterior* heart, from its situation,—and *pulmonary* from the pulmonary artery arising from it. The other is for the circulation of arterial blood, and is hence called *arterial heart*, also *left* or *posterior*, from its situation,—*aortic heart*, because the aorta arises from it; and *systemic*, because the blood is sent from it to the general system.

The whole of the vessels communicating with the right heart contain venous blood; those of the left side arterial blood.

If we consider the heart to be the centre, two circulations must be accomplished, before the blood, setting out from one side of the heart, performs the whole circuit. One of these consists in the transmission of the blood from the right side of the heart, through the lungs, to the left; the other, in its transmission from the left side, along the arteries, and by means of the veins, back to the right. The former is called the *lesser* or *pulmonic*, the latter the *greater* or *systemic* circulation. The organs, by which these are effected, will require a more detailed examination.

1. ANATOMY OF THE CIRCULATORY ORGANS.

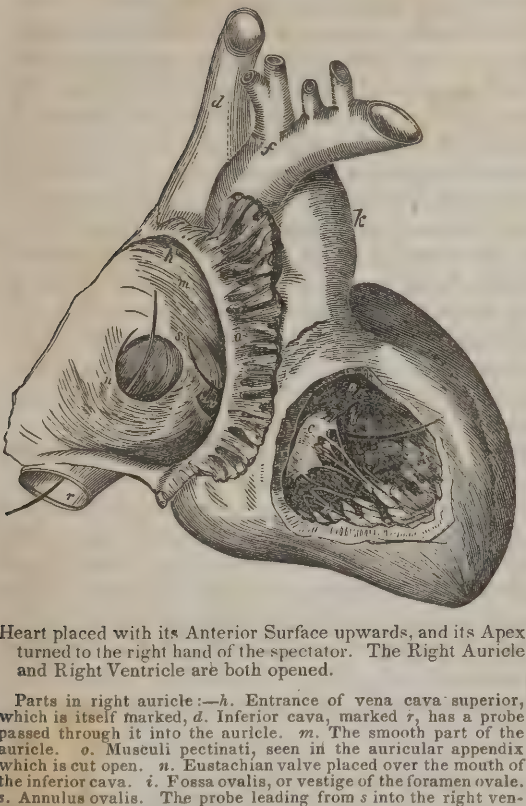
The circulatory apparatus is composed of organs by which the blood is put in motion, and along which it passes during its circuit.

a. *Heart.*

To simplify the consideration of the subject, we shall consider the heart double; and that each system of circulation is composed of a *heart;* of *arteries*, through which the blood is sent from the heart; and of *veins*, by which the blood is returned to it. At the minute termination of each of these is a *capillary system.* We shall first describe the central organ as forming two distinct hearts; and afterwards the two united.

The *pulmonic*, *right* or *anterior heart*, called also *heart of black blood*, is composed of an auricle and a ventricle. The *auricle*, so termed from some resemblance to a small ear, is situate at the base of the organ, and receives the whole of the blood returned from various parts of the body by three veins;—the two venæ cavæ, and the coronary. The *vena cava descendens* terminates in the auricle in the direction of the aperture by which the auricle communicates with the ventricle. The *vena cava ascendens*, the termination of which is directed more backwards, has the remains of a valve which is much larger in the fœtus, called

Fig. 275.

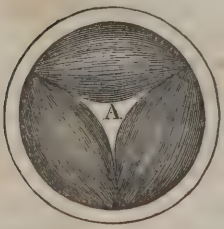


Heart placed with its Anterior Surface upwards, and its Apex turned to the right hand of the spectator. The Right Auricle and Right Ventricle are both opened.

Parts in right auricle:—*h*. Entrance of vena cava superior, which is itself marked, *d*. Inferior cava, marked *r*, has a probe passed through it into the auricle. *m*. The smooth part of the auricle. *o*. Musculi pectinati, seen in the auricular appendix which is cut open. *n*. Eustachian valve placed over the mouth of the inferior cava. *i*. Fossa ovalis, or vestige of the foramen ovale. *s*. Annulus ovalis. The probe leading from *s* into the right ventricle passes through the auriculo-ventricular opening. *v*. Mouth of the coronary vein. Parts in the right ventricle, in which the other end of the probe, from *s*, appears:—*a*. Cavity of conus arteriosus. leading to the pulmonary artery, *k*. *l*. Convex septum between the ventricles. *c*. Anterior segment of the tricuspid valve connected by slender cords, the chordæ tendineæ, to the musculi papillares, *e*. *f*. The aorta.

valve of Eustachius. The third vein is the *cardiac* or *coronary;* it returns the blood from the heart which has been carried thither by the coronary artery. In the septum between the right and left auricle, there is a superficial depression, about the size of the point of the finger, which is the *vestige* of the foramen ovale,—an important part of the circulatory apparatus of the fœtus. The opening, through which the auricle projects its blood into the ventricle, is situate downwards and forwards, as seen in Fig. 275. The inner surface of the *proper auricle*, or that which more particularly resembles the ear of a quadruped,—the remainder being sometimes called *sinus venosus* or *sinus venarum cavarum*, — is distinguished by having a number of *fleshy pillars* in it, which, from their supposed resemblance to the teeth of a comb, are called *musculi pectinati.* They are mere varieties, however, of the *columnæ carneæ* of the ventricles.

Fig. 276.



Semilunar Valves closed.

The right *ventricle* or *pulmonary ventricle* is situate in the anterior part of the heart; the base and apex corresponding to those of the heart. Its cavity is generally greater than that of the left side, and its parietes not so thick, owing to its having merely to force the blood through the lungs. It communicates with the auricle by the *auriculo-ventricular opening—ostium venosum;* and the only other opening into it is that which communicates with the interior of the pulmonary artery. The opening between the auricle and ventricle is furnished with a tripartite valve, called *tricuspid* or *triglochin;* and the

pulmonary artery has three others, the *sigmoid* or *semilunar*. From the edge of the tricuspid valve, next the apex of the heart, small, round, *tendinous cords*, called *chordæ tendineæ*, are sent off, which are fixed, as represented in Fig. 275, to the extremities of a few strong *columnæ carneæ*—called *musculi papillares*. These tendinous cords are of such a length as to allow the valve to be laid against the sides of the ventricle, in the dilated state of that organ, and to admit of its being pushed back by the blood, until a nearly complete septum is formed during the contraction of the ventricle. The *semilunar* or *sigmoid valves* are three in number, situate around the artery. When these fall together, there must necessarily be a space left between them. To obviate the inconvenience that would result from the existence of such a free space, a small granular body is attached to the middle of the margin of each valve; and these, coming together, as at A, Fig. 276, when the valves are shut down, complete the diaphragm, and prevent any blood from passing back to the heart. These small bodies are termed, from their reputed discoverer, *corpuscula Arantii* and also *corpuscula Morgagnii;* or, from their resemblance to the seed of the sesamum, *corpuscula sesamoidea*. The valves, when shut, are concave towards the lungs, and convex towards the ventricle. Immediately above them the artery bulges out, forming three sacculi or sinuses, called *sinuses of Valsalva*. These are often said to be partly formed by the pressure of the blood upon the sides of the vessel. The structure is doubtless ordained, and is admirably adapted for a specific purpose,—namely, to allow the free edges of the valves to be readily caught by the refluent blood, and thus facilitate their closure. Within the right ventricle, and especially towards the apex of the heart, many strong eminences are seen, *columnæ carneæ* (Fig. 275). These run in different directions, but the strongest of them longitudinally with respect to the ventricle. They are of various sizes, and form a beautifully reticulated texture. Their chief use probably is, to strengthen the ventricle, and prevent it from being over-distended; in addition to which they may tend to mix the different products of absorption.

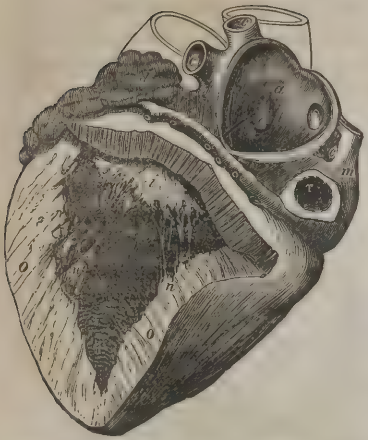
Fig. 277.

Part of the Left Ventricle, and commencement of the Aorta laid open to show the Sigmoid Valves.

a. Portion of the aorta. *v*. Muscular wall of left ventricle. 1, 2, 3. Semilunar or sigmoid valves. *c*. Corpus Arantii in one of them. *e*. Thin lunated marginal portion or lunula. *s*, *t*, *t*. Sinuses of Valsalva. *t*, *t*. Mouths of the two coronary arteries of the heart. *m*. Anterior segment of the mitral valve, the fibrous structure of which is continuous above with the aortic tendinous zone, opposite the attached margin of the sigmoid valve, marked 1. Opposite the valves, 2 and 3, the tendinous zone receives below the muscular substance of the ventricle, *v*. *h*. Larger chordæ tendineæ. *o*, *o*. Musculi papillares.

The *corporeal*, *left*, *aortic* or *systemic* heart,—called also *heart of red blood*,—has likewise an auricle and a ventricle. The *left auricle* is considerably thicker and stronger but smaller than the right; and it is likewise divided into *sinus venosus* and *proper auricle*, which form a

Fig. 278.



Heart seen from behind, and having the Left Auricle and Ventricle opened.

Parts in left auricle:—*a*. Smooth wall of auricular septum. *c*, *c*, *c*. Openings of the four pulmonary veins. *d*. Left auricular appendage. *e*. Slight depression in the septum, corresponding to the fossa ovalis on the right side. A probe is seen which passes down into the ventricle through the auriculo-ventricular orifice. Parts in left ventricle:—*i*. Posterior segment of the mitral valve, behind which is the probe passed from the left auricle. *n*, *n*. The two groups of musculi papillares. *o*. Section of the thick walls of this ventricle, which may be compared with that of the walls of the right ventricle, Fig. 275. *r*. Entrance of inferior cava.

common cavity. The columns in the latter are like those of the right, but less distinct. From the under part of the auricle, a circular passage, termed *ostium arteriosum* or "auricular orifice," leads to the posterior part of the base of the cavity of the left ventricle. The left auricle receives the blood from the pulmonary veins. The *left* or *aortic ventricle* is situate at the posterior and left part of the heart. Its sides are three times thicker and stronger than those of the right ventricle, to adapt it for the much greater force it has to exert; for, whilst the right ventricle merely sends its blood to the lungs, the left ventricle transmits it to every part of the body. Its muscular force has been estimated at twice that of the right.[1] It is narrower and rounder, but considerably longer, than the right ventricle, and forms the apex of the heart. The internal surface of this ventricle has the same general appearance as the other; but differs from it in having larger, more numerous, firmer, and stronger columnæ carneæ. In the aperture of communication with the corresponding auricle, there is here, as in the opposite side of the heart, a ring or zone, from which a valve, essentially like the tricuspid, goes off. It is stronger, however, and divided into two principal portions only; the chordæ tendineæ and *musculi papillares*, are also stronger and more numerous. This valve has been termed *mitral*, from some supposed resemblance to a bishop's mitre. At the fore and right side of the valve, and behind the commencement of the pulmonary artery, a round opening exists, which is the mouth of the aorta. Here are three *semilunar valves*, with their *corpuscula Arantii;* like those of the pulmonary artery, but a little stronger; and, on the outer side of the semilunar valves, are the *sinuses of Valsalva*, a little more prominent than those of the pulmonary artery.

The structure of the two hearts is the same. A serous membrane covers both. It is an extension of the inner membrane of the pericardium.

The substance of the heart is essentially muscular. The fibres run in different directions, longitudinally and transversely, but most of them obliquely. Many pass over the point, from one heart to the other, and all are so involved as to render it difficult to unravel them. The cavi-

[1] Valentin, Lehrbuch der Physiologie des Menschen, i. 415, Braunschweig, 1844.

ties are lined by a thin membrane, *endocardium*, which differs somewhat in the two hearts;—being in one a prolongation of the inner coat of the aorta, and in the other, of the venæ cavæ. On this account, the inner coat of the left heart is but slightly extensible, more easily ruptured, and considerably disposed to ossify; that of the right heart, on the other hand, is very extensible, not readily ruptured, and but little liable to ossify. M. Deschamps[1] has described a membrane, which is situate between the endocardium and the areolar tissue that lines the muscular structure at its inner surface, and belongs essentially to the elastic fibrous tissue. The tissue of the heart is supplied with blood by the *cardiac* or *coronary arteries*—the first division of the aorta; and their blood is conveyed back to the right auricle by the *coronary veins*. The nerves, which follow the ramifications of the coronary arteries, proceed chiefly from a plexus, formed by the spinal nerves and great sympathetic. Besides the large ganglia on the cardiac plexuses at the base of the organ, the nerves present minute ganglia along their course in its substance; and Dr. Robert Lee[2] has affirmed, that it can be clearly demonstrated, that every artery distributed throughout the walls of the heart, and every muscular fasciculus of the organ, is supplied with nerves upon which ganglia are formed. The results of Dr. Lee's observations are not, however, considered by all to be established.[3]

In both hearts, the auricles are much thinner and more capacious than the ventricles; but they are themselves much alike in structure and size. The observation, that the right ventricle is larger than the left, is as old as Hippocrates, and has been attempted to be accounted for in various ways. Some have ascribed it to original conformation; others to the blood being cooled in its passage through the lung, and therefore occupying a smaller space when it reaches the left side of the heart. Haller[4] and Meckel[5] assert, that it is dependent upon the kind of death; that if the right ventricle be usually more capacious, it is owing to the lung being one of the organs that yields first, thus occasioning accumulation of blood in the right cavities of the heart; and they state that they succeeded, in their experiments, in rendering either one or the other of the ventricles more capacious, according as the cause of death arrested first the circulation in the lung or in the aorta; but the experiments of Legallois[6] and Seiler,[7] especially of the former, upon dogs, cats, Guinea pigs, rabbits, in the adult, the child, and the still-born fœtus, with mercury poured into the cavities, have shown that, except in the fœtus, the right ventricle is more capacious, whether death has been produced by suffocation, in which the blood is accumulated in the right side of the heart, or by hemorrhage; and Legallois[8] thinks, that the difference is owing to the left ventricle being more muscular,

[1] Gazette Médicale de Paris, No. 10, and Encyclographie des Sciences Médicales, Avril, 1840, p. 281.

[2] Philosophical Transactions, Part i. for 1849.

[3] British and Foreign Medico-Chirurgical Review, p. 550, Oct., 1849.

[4] Element. Physiol., iv. 3, 3.

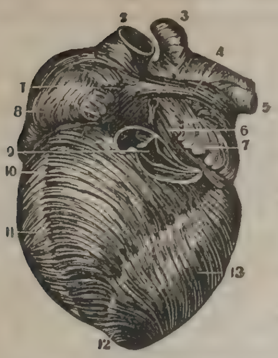
[5] Handbuch der Menschlichen Anatomie, Halle, 1817, s. 46; or the translation from the French version, by Dr. Doane, Philad., 1832.

[6] Dict. des Sciences Médicales, v. 440.

[7] Art. Herz. in Pierer's Anat. Physiol. Real Wörterb., iv. 32, Leipz., 1821.

[8] Œuvres, Paris, 1824.

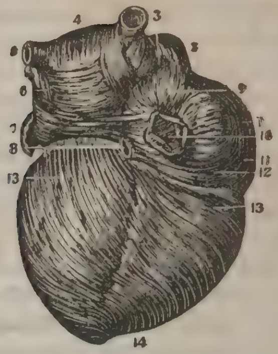
Fig. 279.



Anterior View of External Muscular Layer of the Heart after removal of its Serous Coat, &c.

1. Right auricle. 2. Descending vena cava. 3. Right anterior pulmonary vein. 4. Horizontal band of fibres passing across the base of the auricles. 5. Left anterior pulmonary vein. 6. Muscular fibres between auricles. 7. Fringed or ring-shaped bands of fibres at the extremity of left auricle. 8. Muscular fibres at the base of right auricle. 9. Section of pulmonary artery, showing semilunar valves. 10, 11. Anterior bis-ventricular muscular fibres. 12, 13. Their continuation on to left ventricle.

Fig. 280.



Posterior View of the same.

1. Right auricle. 2. Descending vena cava. 3. Right posterior pulmonary vein. 4. Muscular fibres of left auricle. 5. Left posterior pulmonary vein. 6, 7. Arrangement of muscular fibres at the end of left auricle. 8. Orifice of great coronary vein. 9. Band of fibres between the two venæ cavæ. 10. Orifice of the ascending vena cava; Eustachian valve is at the end of the line. 11, 12. Muscular fibres at the base of auricle. 13, 14. Muscular fibres in the ventricles.

and, therefore, returning more upon itself. The capacity of each of the ventricles in the full-sized heart has been estimated at about two fluid ounces;[1] but by Valentin at more than double that amount.[2]

The two hearts, united together by a median septum, form, then, one organ, which is situate in the middle of the chest, (see Fig. 265,) between the lungs, and, consequently, in the most fixed part of the thorax. Figure 281 is modified from one carefully made from nature by Dr. Pennock.[3] It represents the normal position of the heart and great vessels.

According to Carus,[4] the weight of the heart compared with that of the body is as 1 to 160. M. J. Weber[5] found the proportion, in one case, to be 1 to 150; Dr. Clendinning[6] that of the male to be 1 to 160; that of the female 1 to 150; and Laënnec considered the organ to be of a healthy size when equal to the fist of the individual. M. Cruveilhier estimates the mean weight at six or seven ounces. M. Bouillaud[7] weighed the hearts of thirteen subjects, in whom, from the general habit, previous state of health, and mode of death, there was every reason to believe that they were in the natural state. The mean was eight ounces and three drachms. From all his data he is led to fix the average weight of the heart, in the adult, from the 25th to the 60th year,

[1] Quain and Sharpey's edit. of Quain's Human Anatomy, Amer. edit., by Leidy, ii. 487, Philad., 1849. [2] Lehrbuch der Physiologie des Menschen, i. 415.

[3] Medical Examiner, April 4, 1840.

[4] Introduction to Comp. Anat., translated by R. T. Gore, Lond., 1827.

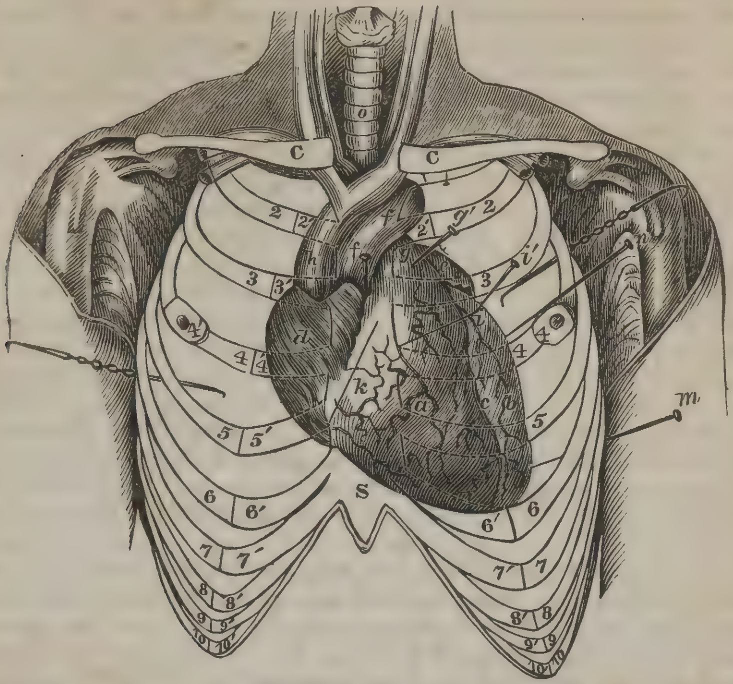
[5] Hildebrandt's Handbuch der Anatomie, von E. H. Weber, Braunschweig, 1831, Band. iii. s. 125.

[6] Journal of the Statistical Society of London, July, 1838.

[7] Traité Clinique des Maladies du Cœur, &c., Paris, 1835.

at from 8 to 9 ounces. Dr. Clendinning carefully examined nearly four hundred hearts of persons of both sexes, and of all ages above

Fig. 281.



View of the Heart in situ.

S. Outline of sternum. C, C. Clavicles. 1, 2, 3, 4, 5, 6, &c. Ribs. 1′, 2′, 3′, 4′, 5′, 6′, &c. Cartilages of ribs. 4′′. Right and left nipples. *a*. Right ventricle. *b*. Left ventricle. *c*. Septum between ventricles. *d*. Right auricle. *e*. Left auricle. *f*. Aorta. *f*′. Needle passing through aortic valves. *g*. Pulmonary artery. *g*′. Needle passing through valves of pulmonary artery. *h*. Vena cava descendens. *i*. Line of direction of mitral valve; dotted portion posterior to the right ventricle. *i*′. Needle passed into mitral valve at its extreme left. *k*. Line of tricuspid valve. *o*. Trachea.

puberty. The average weight was about nine ounces avoirdupois,—much less than that observed by Dr. John Reid,[1] who found the average weight of the male heart—of 89 weighed—to be 11 oz. and 1 dr.; and of the female heart—of 53 weighed—to be 9 oz. and ½ dr. The weight and dimensions of the organ, according to Lobstein and Bouillaud, are as follows:—Weight, 9 to 10 ounces; length from base to apex, 5 inches 6 lines; breadth at the base, 3 inches; thickness of walls of left ventricle, 7 lines; do. at a finger's breadth above the apex, 4 lines; thickness of walls of right ventricle, 2¼ lines; do. at apex, ½ a line; thickness of right auricle, 1 line; do. of left auricle, ½ a line. M. Bizot[2] has given the following measurements, taking the average of males from 16 to 89 years.

[1] Lond. and Edinb. Monthly Journal of Med. Science, April, 1843, p. 322.

[2] For the results of M. Bizot's researches, to ascertain the dimensions of the heart and arteries, see Mémoires de la Société Médicale d'Observation, Paris, 1837; and Hope on the Diseases of the Heart, Amer. edit., by Dr. Pennock, p. 234, Philad., 1842.

	Base.	Middle.	Apex.
Left ventricle	$4\frac{1}{2}$ lines	$5\frac{1}{6}$	$3\frac{3}{4}$
Right ventricle	$1\frac{15}{16}$	$1\frac{3}{8}$	$1\frac{1}{30}$

In the female, the average thickness is something less. Dr. Ranking[1] has published the results of measurements, evidently made with accuracy, of upwards of 100 hearts,—care being taken to exclude all those that exhibited any trace of organic change. The following are the *mean* admeasurements. Of 15 male hearts, the mean *circumference* was $9\frac{27}{48}$ths inches; of 17 female hearts, $8\frac{16}{48}$ths inches. The mean *length* of the male heart was $4\frac{16}{48}$ths inches; of the female, $4\frac{36}{48}$ths. The mean *thickness* of the left ventricle, in the male, was $\frac{27}{48}$ths of an inch; in the female, $\frac{23}{48}$ths; of the right ventricle, in the male, $\frac{8}{48}$ths; in the female, $\frac{6}{48}$ths. The septum ventriculorum has, in the male, a mean thickness of $\frac{22}{48}$ths of an inch; in the female, $\frac{14}{48}$ths. The aortic orifice, in the male, had a mean circumference of $2\frac{34}{48}$ths inches; the right auriculo-ventricular orifice, $4\frac{35}{48}$ths inches; the left auriculo-ventricular orifice, $3\frac{45}{48}$ths inches. The corresponding parts of the female were relatively less. Dr. Ranking infers, that the heart of the male is larger than that of the female,—that the length of the healthy heart is to its circumference rather less than 1 to 2,—that the thickness of the parietes of the right ventricle to the left is as 1 to 3 nearly:—that the pulmonary artery is slightly wider than the aorta; and, lastly, that the right auriculo-ventricular opening is considerably larger than the left.

It need scarcely be said, that the weight and dimensions of the organ must vary according to the age, sex, &c., of the individual. M. Bizot[2] found, that the influence of stature on its size was slight; and not such as might have been expected *à priori;* for, in individuals of the male sex above sixty inches, and in females above fifty-five inches, in height, the mean dimensions of the organ, especially its breadth, were less than in persons of a lower stature. He found the width of the shoulders furnish a better proportionate standard of its measurement,—the distance between the acromial point of the clavicles, and the length and breadth of the heart increasing in a tolerably regular ratio. Numerous measurements of the organ have been made on children by MM. Rilliet and Barthez;[3] whence it results: *First.* That its circumference does not augment in proportion to age. It is nearly the same from 15 months to five years and a half; and from the latter age it goes on increasing irregularly until puberty. *Secondly.* The distance from the base to the apex is nearly one-half the total circumference at the base of the ventricles. *Thirdly.* The maximum thickness of the parietes of the right ventricle varies but little according to age. It is generally 0·078 Eng. inch to the age of six years; and after this from 0·118 to 0·157. *Fourthly.* The maximum thickness of the left ventricle remains below 0·393 Eng. inch, until six years of age. Later, it is habitually 0·393, or a little more. *Fifthly.* The proportion between the thickness of the two ventricles is generally, as stated by M. Guersant, as 3 to 1, or 4 to 1,

[1] London Medical Gazette, No. xxiv., 1842.

[2] Mémoires de la Société Médicale d'Observation de Paris, tom. 1ère, Paris, 1836.

[3] Traité Clinique et Pratique des Maladies des Enfants, iii. 662, Paris, 1843.

rather more than less. *Sixthly.* The maximum thickness of the septum is nearly the same as that of the left ventricle, a little more rather than less. *Seventhly.* The seat of the maximum thickness of the right ventricle is at the base, and near the auriculo-ventricular orifice; that of the left ventricle one or two centimètres (in. 0·393 or 0·796) from the base; and that of the septum from two to three centimètres (in. 0·796 to 1·171). *Eighthly.* The size of the right auriculo-ventricular orifice remains nearly the same until the age of 5 years; it scarcely increases in size up to the age of 10; but then augments more manifestly. *Ninthly.* The left auriculo-ventricular orifice, which is always smaller than the right, increases a little more regularly than it with age, and frequently has the same dimensions as the distance from the base of the heart to its apex. *Tenthly.* The aortic orifice presents but a slight augmentation from 15 months to 13 years of age. *Eleventhly.* The pulmonary artery, on the other hand, increases notably from the age of six years to eight, so that although before this period it is equal to or scarcely greater than the aortic orifice, afterwards it is commonly much larger. They did not find any marked difference between the male and female heart in children.

The heart is surrounded by its proper capsule, called *pericardium*,—a fibro-serous membrane, composed of two layers. The outermost of these is fibrous, semi-transparent, and inelastic; strongly resembling the dura mater in its texture. Its thickness is greater at the sides than below, where it rests upon the diaphragm; or than above, where it passes along the great vessels which communicate with the heart. The inner layer is of a serous character, and lines the outer, giving the polish to its cardiac surface; it is then reflected over the heart, and adheres to it by areolar substance. Like other serous membranes, it secretes a fluid, termed *liquor pericardii*, to lubricate the surface of the heart. This fluid is always found in greater or less quantity after death; and a question has arisen as to the amount that should be considered morbid. This must obviously vary according to circumstances. In the healthy condition, it is seldom above a tea-spoonful. When its quantity is augmented, the disease *hydropericardium* exists. Its great use probably is to keep the heart constantly moist by the exhalation effected from it; and, also, to restrain the movements of the organ, which, under the influence of the emotions, sometimes leaps inordinately. If the pericardium be divided in a living animal, the heart is found to bound, as it were, from its ordinary position; and hence the expression,—"leaping of the heart,"—during emotion, is physiologically accurate.

b. *Arteries.*

Arteries are solid, elastic tubes, which arise, by a single trunk, from the ventricle of each heart, and gradually divide and subdivide, until they are lost in the capillary system. The large artery, which arises from the left ventricle, and conducts the blood to every part of the body,—even to the lungs, so far as regards their nutrition,—is the *aorta;* and that, which arises from the right ventricle and conveys venous blood to the lungs for aeration, is the *pulmonary artery.* Neither the one nor the other is the continuation of the proper tissue

of the ventricles; the inner membrane is alone continuous—the muscular structure of the heart being united to the fibrous coat of the arteries by means of an intermediate fibrous tissue. The *aorta*, as soon as it quits the left ventricle, passes beneath the pulmonary artery, is entirely concealed by it, and ascends to form a curvature with the convexity upwards, the summit of which rises to within three quarters of an inch or an inch of the superior edge of the sternum. This great curvature is called the *cross* or *arch of the aorta*. The vessel then passes downwards, from the top of the thorax to nearly as far as the sacrum, where it divides into two trunks, one of which proceeds to each lower extremity. In the whole of this course, it lies close to the spine, and gives off the various branches that convey arterial blood to the different parts of the body. Of the immense multitude of these ramifications an idea may be formed, when we reflect, that the finest pointed needle cannot be run into any part of the surface of the body, without blood,—probably both arterial and venous,—flowing. The larger arteries are situate deeply, and are thus remote from external injury. They communicate freely with each other, and their anastomoses are more frequent as the arteries become smaller and farther from the heart. At their final terminations, they communicate with the veins and lymphatics.

It has been a common, but erroneous belief, that the branches of the aorta, when taken collectively, are of much greater capacity than the parent trunk, and that this excess goes on augmenting; so that the ultimate divisions of an artery are of much greater capacity than the parent trunk. Hence, the arterial system has been considered to represent, in the aggregate, a cone, whose apex is at the heart, and base in the organs; but as all the minute arterial ramifications are not visible, it is obviously impracticable to discover the ratio between their united capacity and that of the aorta at its origin: yet the problem has been attempted. Keill, by experiments made on an injected subject, considered it to be as 44,507 to 1: J. C. A. Helvetius and Sylva as 500 to 1. Sénac estimated, not their capacities but their diameters, and conceived the ratio of these to be as 118,490 to 90,000; and George Martine affirmed, that the calibre of a parent arterial trunk is equal to the cube root of the united diameters of the branches.[1] It will be shown, however, hereafter, from the observations of M. Poiseuille and Mr. Ferneley, that the notion of the much greater capacity of the branches than of the parent trunk is a fallacy. This subject will be referred to hereafter.

The *pulmonary artery* strongly resembles the aorta. Its distribution has been already described as a part of the respiratory organs.

The *arteries* are composed of different coats in superposition, respecting the number of which anatomists have not been entirely of accord. Some have admitted six; others five; others four; but at the present day, three only are perhaps generally received;—first, an *external*, *areolar* or *cellular*, called also *nervous*, and *cartilaginous* by Vesalius, and *tendinous* by Heister, which is formed of condensed areolar substance, and

[1] Haller, Element. Physiolog., lib. ii., sect. 1, § 18, Lausan., 1757.

has considerable strength and elasticity, so that if a ligature be applied tightly round the vessel, the middle and internal coats may be completely cut through, whilst the outer coat may remain entire. Scarpa is not disposed to admit this as one of the coats. He considers it only an exterior envelope, to retain the vessel *in situ*. The next coat is the *middle*, *muscular* or *proper* coat, the character of which has been the subject of much discussion. It was, at one time, almost universally believed to be muscular. Such was the opinion of Mr. Hunter.[1] Henle[2] advances the opinion, that its structure is intermediate between areolar and muscular tissue; its microscopic elements being broad and very flat, slightly granulated fibres or bands, which lie in rings around the internal membrane, and are about 0·003 lines in diameter. These with a system or network of dark streaks constitute the middle coat. In the large arteries, as the aorta and its main branches, nearly the whole thickness of this coat is composed of yellow elastic tissue—the *tissu jaune* of the French anatomists: few muscular fibres are perceptible; but in the smaller arteries the proportionate thickness of the elastic coat gradually diminishes; whilst, as a general rule, the muscular fibres increase in number, and form a layer within the elastic coat. The muscular fibres resemble those of the intestinal tube, being of the nonstriped or nonstriated variety. They are arranged areolarly; are pale and flat, and mingled with filaments of fine elastic tissue.

Nysten,[3] Magendie,[4] and Müller[5] applied the galvanic stimulus to the middle coat, which is the most sensible test of irritability, but without effect. It is proper, however, to remark, that the heart seems equally unsusceptible of the galvanic stimulus; or at least is not affected by it like the voluntary muscles. In the cases of two executed criminals, which the author had an opportunity of observing, although all degrees of galvanism were applied half an hour after the drop fell, no motion whatever was perceptible; yet the voluntary muscles contracted, and continued to do so for an hour and a half after execution. The same fact is recorded in the galvanic experiments of Dr. Ure, detailed in another part of this work, (vol. i. p. 408,) and is attested by Bichat, Treviranus and others. Humboldt, Pfaff, J. F. Meckel, Wedemeyer, and J. Müller, however, affirm the contrary. The last observer states,[6] that with a single pair of plates he excited contractions not only in a frog's heart, which had ceased to beat, but also in that of a dog, under similar circumstances. Into the subject of the cause of the heart's action, we shall, however, inquire presently. Müller[7] suggests, that in the capability to contract under the influence of cold, as exhibited in the experiments of Schwann, referred to here-

[1] On the Blood, Inflammation and Gunshot Wounds; by Palmer, Amer. edit., p. 156, Philad., 1840.

[2] Casper's Wochenschrift, May 23, 1840, cited in Brit. and For. Med. Rev., Oct., 1840, p. 551.

[3] Recherches de Physiologie, &c., p. 325, Paris, 1811.

[4] Précis, 2de édit., ii. 387, Paris, 1825.

[5] Handbuch der Physiologie, Baly's translation, p. 205, Lond., 1838.

[6] Loc. cit.

[7] Archiv. fur 1836, in Lond. Med. Gaz., May, 1837.

after, the contractile tissue of the arteries resembles that of the dartos, and that found in many parts of the skin, as about the nipple and follicles, although the physical characters of the latter are so different from elastic tissue. The *third* or *inner coat* is smooth and polished, and a continuation of the membrane that lines the ventricles. It has an epithelial lining, resembles the serous membranes, and is lubricated by a form of serous exhalation.[1]

The arteries receive the constituents that belong to every living part,—arteries, veins, lymphatics, and nerves. These arteries do not proceed from the vessels they nourish, but from adjacent trunks, as we have remarked of the *vasa vasorum*, to which class they really belong. The nerves proceed from the great sympathetic; form plexuses around the vessels, and accompany them through all their ramifications. By some anatomists, the arteries of the head, neck, thorax, and abdomen, are conceived to be supplied from the great sympathetic, whilst those of the extremities are supplied from the nerves of the spinal marrow. It is probable, however, that more accurate discrimination might trace the dispersion of twigs of the nerves of involuntary motion on all these vessels. The organization of the arteries renders them tough and extremely elastic, both of which qualities are necessary to enable them to withstand the impulse of the blood sent from the heart, and to react upon the fluid so as to influence its course. It is by virtue of this structure, that the parietes retain their form in the dead body,—one of the points that distinguish them from the veins.

The vitality of the arteries is inconsiderable. Hence their diseases are by no means numerous or frequent,—an important fact, seeing that their functions are essential, and their activity incessant.

c. *Intermediate, Peripheral or Capillary System.*

The capillary or intermediate vessels are of extreme minuteness, and are by some considered to be formed by the terminations of arteries and the commencement of veins; by others to be a distinct set of vessels. This system forms a plexus which is distributed over every part of the body, and constitutes, in the aggregate, what is meant by the *capillary system*. It admits of two great divisions, one situate at the termination of the branches given off from the aorta, and called the *general capillary system;* the other at the termination of the branches of the pulmonary artery,—the *pulmonic capillary system*. Although the capillary system of man does not admit of detection by the unaided sight, its existence is evidenced by the microscope; by injections, which develope it artificially in almost every organ; by the application of excitants, and by inflammation. The parietes frequently cannot be distinguished from the substance of the tissues;—the colour of the blood, or the matter of the injection alone indicating their course. In some parts, as in the white textures, these vessels do not seem to admit the red particles of the blood, whilst others admit them always. This

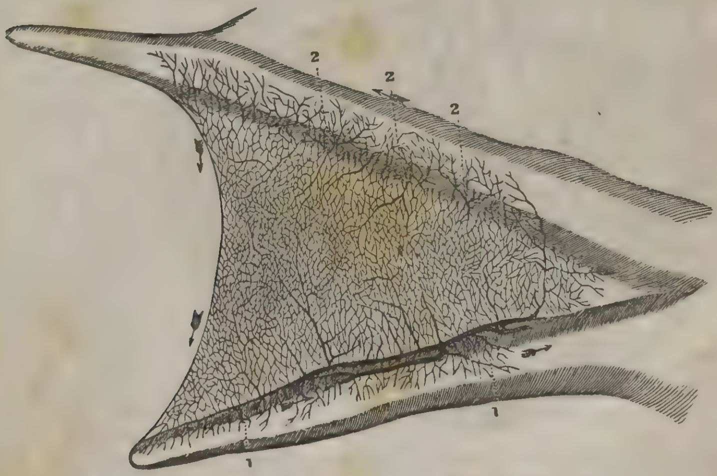
[1] For some speculations as to the agency of this secretion in the production of the buffy state of the blood, &c., see M. Romain Gérardin, in Journal des Connaissances Médico-Chirurgicales, Mars, 1836.

diversity gave rise to a distinction of the capillaries into *red* and *white;* but there are probably none of the latter. It is difficult, indeed, to conceive how the red particles could be arrested at the mouths of the white arteries—if such existed—without their preventing altogether the entrance of blood into them. The true cause of the whiteness appears to be the small quantity of blood they receive; and it is only when the network is very close, and the quantity of blood passing through them great, that a perceptible colour is produced. If a plate of red glass be reduced to a very thin pellicle, and be placed between the eye and light, its colour will be scarcely sensible. To perceive it, several of these pellicles must be placed over each other, and they must be examined not by their transparency, but by causing the light to fall on their surface, or by reflection.

There are certain textures, again, which receive no bloodvessels,—the corneous and epidermic, for example. They are probably nourished by transudation of nutritive matter from the vessels of the surrounding tissue.

The ancients were of opinion, that arteries and veins are separated by an intermediate substance, consisting of a fluid effused from the blood, which they called, in consequence, *parenchyma.*[1] The notion is, indeed, still entertained; and is considered to be supported by microscopical observations. In the examination of delicate and transparent tissues, currents of moving globules are seen with many spaces of apparently solid substances, resembling small islets, surrounded by an agitated fluid. If the tissue be irritated by thrusting a fine needle into

Fig. 282.

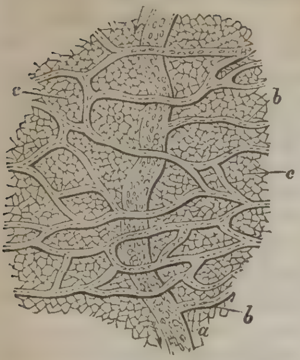


Circulation in the Web of the Frog's Foot. (Wagner.)
1, 1. Veins. 2, 2. Arteries.

it, the motion of the globules becomes more rapid; new currents arise where none were previously perceptible, and the whole becomes a mass

[1] Galen. Administrat. Anatom., vi. 2.

Fig. 283.

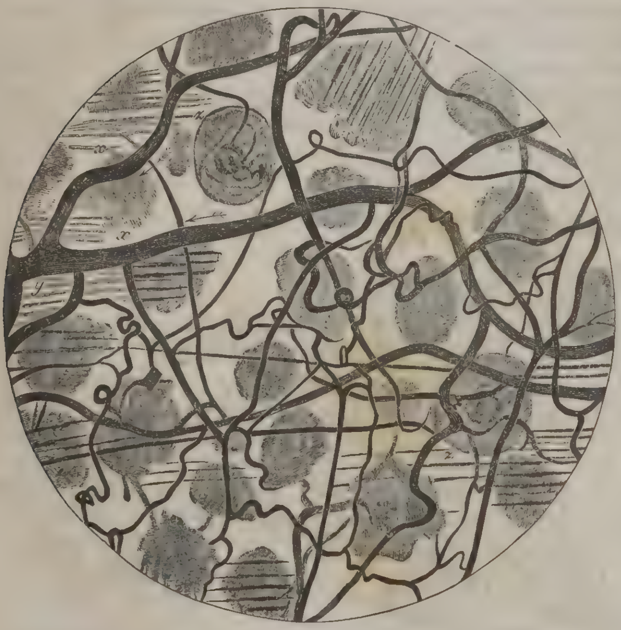


Portion of the Web of the Frog's Foot.

a. A deeper lying venous trunk, with which two smaller capillary veins, *b b*, communicate *c, c.* The angular unnucleated cells of the parenchyma. (Wagner.)

of moving particles, the general direction of which tends towards the points of irritation. But although a part of the apparatus of intermediate circulation may be arranged, in this manner, there are reasons for the belief, that a more direct communication between the arteries and veins exists also. The substance of an injection passes from one set of vessels into the other, without any evidence of intermediate extravasation. The blood has been seen, too, passing in living animals, directly from the arteries into the veins. Leeuenhoek[1] and Malpighi,[2] on examining the swim-bladders, gills, and tails of fishes, the mesentery of frogs, &c.—which are transparent,—observed this distinctly; and the fact has been proved by the observations of Cowper, Cheselden, Hales, Spallanzani, Thomson, Cuvier, Configliachi, Rusconi, Döllinger, Carus, and others.

Fig. 284.



Circulation in the Under Surface of the Tongue of the Frog. (Donné.)

x, x. Venous branches uniting to form a principal vein, *y* *z, z.* Follicles into which a small artery enters, which becomes convoluted before issuing from them. A beautiful capillary rete, and some muscular fibres, are also seen.

The artery and vein terminate in two different ways;—at times, after the former has become extremely minute, by sending off numerous lateral branches, as Haller states he noticed in the swim bladders of fishes; at others, by proceeding parallel to each other, and com-

[1] Select Works, containing his Microscopical Discoveries, by Samuel Hooke, p. 90, Lond., 1778.

[2] Epist. de Pulmonibus, 1661, and Haller, Element. Physiol., lib. iii. sect. 3, § 20, Lausann., 1757.

municating by a multitude of transverse branches. Fig. 282 exhibits a microscopic view of the membrane between two of the toes of the hindfoot of the frog, *Rana esculenta*, magnified three diameters.

Fig. 283 shows a portion of the web of a frog's foot magnified 45 diameters. The superficial network of capillaries is seen admitting but a single series of blood particles. All the vessels, here figured, are, according to Wagner,[1] furnished with distinct parietes.

Fig. 284 is a beautiful representation of the circulation in the under surface of the tongue. Along the larger vessels the blood can be seen rushing with excessive velocity. It is proper, however, to state that the more the parts are magnified, the greater will be the apparent velocity. The mean real velocity, Valentin[2] thinks, is one-eighth less in the capillaries than in the veins and arteries.[3] These larger vessels have distinct coats; but single files of globules are seen proceeding slowly through channels to which the author has not been able to satisfy himself that there were distinct parietes. The tongue of the frog offers by far the most satisfactory opportunity for distinctly witnessing the circulation; a fact for the knowledge of which the author is indebted to M. Donné.[4]

The capillary vessels have been esteemed by some to belong chiefly to the arteries, the venous radicles not arising almost imperceptibly from the capillary system, as the arteries terminate in it, but having a marked size at the part where they quit this system, which strikingly contrasts with the excessive tenuity of the capillary arterial vessels; whilst between the capillary system and the arteries there is no distinct line of demarcation. The opinion of Bichat[5] was, that this system is entirely independent of both arteries and veins; and Autenrieth[6] imagined, that the minute arteries unite to form trunks, which again divide before communicating with the veins, so as to represent a system analogous to that of the vena portæ. The experiments of Dr. Marshall Hall[7] on the batrachia, which were performed with signal care, led him to the following conclusions, which agree with those of Bichat, so far as regards the independent existence of a capillary system. The minute vessels, he says, may be considered as arterial, so long as they continue to divide and subdivide into smaller and smaller branches. The minute veins are the vessels that gradually enlarge from the successive addition of small roots. The true capillary vessels are distinct from these. They do not become smaller by subdivision, or larger by conjunction, but are characterized by continual and successive union and division or anastomoses, whilst they retain a nearly uniform diameter. The last branches of the arterial system, and the first root of the venous, Dr. Hall remarks, may be denominated minute, but the term "capillary" must be reserved for, and appropriated to, vessels of a dis-

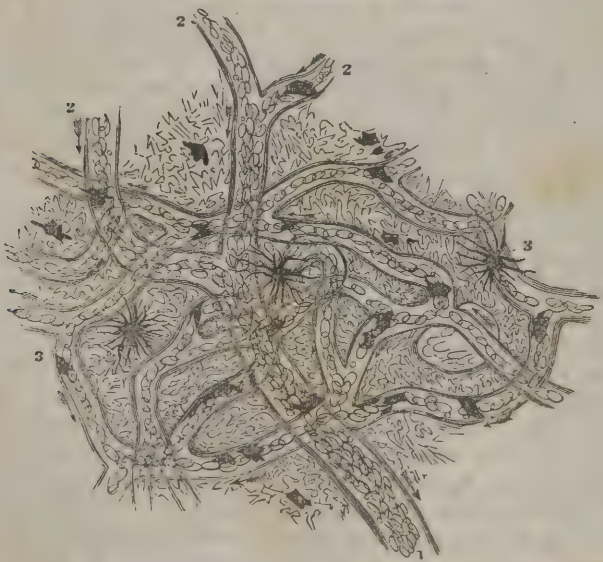
[1] Elements of Physiology, by R. Willis, Lond., 1842.
[2] Lehrbuch der Physiologie des Menschen, i. 467, Braunschweig, 1844.
[3] See also Lebert, Physiologie Pathologique, i. 7, Paris, 1845.
[4] Cours de Microscopie, p. 109, Paris, 1844; and Atlas, planche vi., Paris, 1845.
[5] Anatomie Générale, &c., édit. de MM. Blandin et Magendie, ii. 299, Paris, 1832.
[6] Physiologie, ii. 138.
[7] A Critical and Experimental Essay on the Circulation, &c., Lond., 1830; Amer. edit., Philad., 1835.

tinct character and order, and of an intermediate station, carrying red globules, and perfectly visible by means of the microscope.

Recently, M. Bourgery[1] has maintained, that besides the intermediate vessels, which form the direct communication between the arteries and veins, there is a special capillary arrangement in every tissue by which the functions of nutrition and secretion are accomplished. The diameter of these capillaries, according to M. Bourgery, is not more than one-half, one-third or even one-fourth of that of the blood corpuscles; and they can, consequently, convey only liquor sanguinis. But the existence of these vessels is not considered to be demonstrated; whilst their absence in tissues—as cartilage—which they were formerly supposed to penetrate, has been established.[2]

The capillary arteries are distinct in structure—as they are in office—from the larger arteries. All the coats diminish in thickness and strength, as the tubes lessen in size; but this is more especially the case with the middle coat, which, according to Wedemeyer, may still be distinguished by its colour in the transverse section of any vessel whose calibre is not less than the tenth of a line; but entirely disappears in vessels too small to receive the wave of blood in a manifest jet.

Fig. 285.



Capillaries of the Web of the Frog's Foot.

1. Deep venous trunk, composed of three principal branches, 2, 2, 2; and covered with a rete of smaller vessels. (Wagner.)

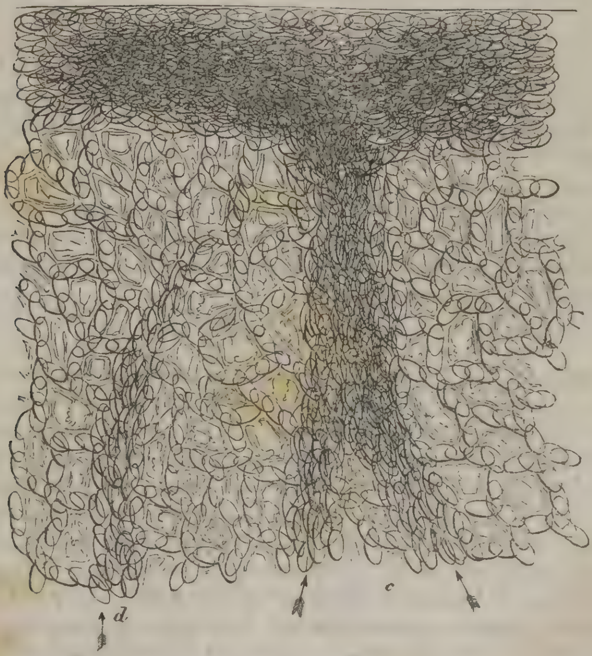
While the coats diminish, the nervous filaments, distributed to them, increase; the smaller and thinner the capillary, the greater the propor-

[1] Comptes Rendus, &c., 1848, and Gazette Médicale, No. 37, 1848.
[2] British and Foreign Medico-Chirurgical Review, p. 527, Oct., 1848.

tionate quantity of its nervous matter. The coats of the capillaries become successively thinner and thinner, and at length disappear altogether; and the vessels—many of them at least—seem to terminate in membraneless canals or interstitial passages, formed in the substance of the tissues. The blood is contained—according to Wedemeyer, Gruithuisen, Döllinger, Carus, and others—in the different tissues in channels, which it forms in them: even under the microscope, the stream is seen to work out for itself, easily and rapidly, a new passage in the tissues, and it is esteemed certain, that in the figura venosa of the egg, the blood is not surrounded by vascular parietes. Most histologists of the day are disposed, however, to believe, that the capillaries are provided with distinct coats. Such, as has been seen, appeared to Wagner to be the case in the frog's foot, when magnified 45 diameters: and it has even been announced, that they are composed of a fibrous structure, analogous to the muscular.

Fig. 285, from Wagner, exhibits the vascular rete and circulation of the web of the hind foot of a frog—*Rana temporaria*—magnified 110 times: here the parietes are very distinct. In Fig. 286, also from Wagner, which represents a portion of a live newt, magnified 150

Fig. 286.



Bloodvessels of the Lung of a Live Newt.

b, *a*. Pulmonary vein receiving blood from another vein, *c*; itself made up of two branches. *d*. Pulmonary artery anastomosing with the pulmonary veins by means of capillary vessels. (Wagner.)

diameters, the capillaries are exceedingly delicate, and their walls by no means as distinct. The arterial and venous trunks and the capillaries

that form the medium of communication between them are well seen, as well as the islets of the substance of the lung, in which a granular or areolar texture is indistinctly perceptible. Dr. Carpenter[1] is of opinion, that the mode of origin of the capillaries refutes the supposition, that they are mere passages channeled out of the tissues through which they convey the blood. He thinks there can be no doubt, that they are produced, in any newly forming tissue, not by the retirement of the cells, one from the other, so as to leave passages between them, but by the formation of communications among certain cells, whose cavities become connected with each other, so as to constitute a plexus of tubes, of which the original cell-walls become the parietes.

Of the minute capillaries,—the diameter of which, in parts finely injected, varies from the $\frac{1}{1000}$th to the $\frac{1}{4000}$th, and the $\frac{1}{5000}$th of an inch and even more,—some, according to Wedemeyer, communicate with veins; in others, there are no visible openings or pores in the sides or ends, by which the blood can be extravasated preparatory to its being imbibed by the veins. There is nowhere apparent a sudden passage of the arterial into the venous stream; no abrupt boundary between the division of the two systems. The arterial streamlet winds through long routes before it assumes the nature, and takes the direction, of a venous streamlet. The ultimate capillary rarely passes from a large arterial into a large venous branch. Many speculations have been indulged regarding the mode in which the vascular extremities of the capillary system are arranged. Bichat regarded it as a vast reservoir, whence originate, besides veins, vessels of a particular order, whose office it is to pour out, by their free extremity, the materials of nutrition,—vessels, which had been previously imagined by Boerhaave, and are commonly known under the appellation of *exhalants*. Mascagni[2] supposed that the final arterial terminations are pierced, towards their point of junction with the veins, by lateral pores, through which the secreted matters transude;—but these points will farther engage attention under Nutrition and Secretion.

d. *Veins.*

The origin of the veins, like that of all capillary vessels, is imperceptible. By some they are regarded as continuous with the capillary arteries; Malpighi[3] and Leeuenhoek[4] state this as the result of their microscopic observations on living animals; and it has been inferred, from the facility with which an injection passes from the arteries into the veins. According to others, cells exist between the arterial and the venous capillaries, in which the former deposit their fluid contents, and whence the latter obtain it. Others, again, substitute a spongy tissue for the cells. It has also been asked,—whether there may not be more delicate vessels, communicating with their radicles, similar to the exhalants which are presumed to exist at the extremities of the arte-

1 Human Physiology, § 477, Lond., 1842.
2 Vasor. Lymph. Corpor. Human. Histor., Sen. 1817; and Prodromo della Grande Anatomie, Firenz., 1819.
3 Secunda Epistola de Pulmonibus, Opera., Lond., 1687.
4 Epistol. 59, Opera., Lugd. Bat., 1722.

ries, and which are regarded as the agents of exhalation. All this is, however, conjectural. It has already been observed, that the mesenteric veins have been supposed by some to terminate by open mouths in the villi of the intestines; and the same arrangement has been conceived to prevail with regard to other veins; but there is no evidence of this. M. Ribes concludes, from the results of injecting the veins, that some of the venous capillaries are immediately continuous with the minute arteries, whilst others open into the cells of the areolar tissue, and into the substance of different organs.

When the veins become visible, they appear as an infinite number of extremely small tubes communicating very freely with each other; so as to form a very fine network. These vessels gradually become larger and less numerous, but still preserve their reticular arrangement; until, ultimately, all the veins of the body empty themselves into the heart by three trunks—the *vena cava inferior*, *vena cava superior*, and *coronary vein*. The *first* of these receives the veins from the lower part of the body, and extends from the fourth lumbar vertebra to the right auricle; the *second* receives all those of the upper part of the body. It extends from the cartilage of the first rib to the right auricle. The coronary vein belongs to the heart exclusively: between the superior and inferior cava a communication is formed by means of the vena azygos.

Fig. 287.

Splenic Vein with its Branches and Ramifications.

1. Trunk of the vein. 2. Gastric branch of this vein coming from the stomach. 3. Branches coming from the substance of the spleen. 4. Small mesenteric vein cut off. 5. Branches coming from external coat of the spleen. 6. Branches of lymphatic vessels of spleen.

Certain organs, as the spleen, appear to be almost wholly composed of venous radicles. Fig. 287 represents the ramifications of the splenic vein, in the substance of that organ; and if we consider, that the splenic artery has corresponding ramifications, the viscus would seem to be almost wholly formed of bloodvessels. The same may be said of the corpus cavernosum of the penis and clitoris, nipple, urethra, glans penis, &c. If an injection be thrown into one of the veins that issue from these different tissues, they are filled by the injection: this rarely occurs, if the injection be forced into the artery. M. Magendie[1] affirms, that the communication of the cavernous tissue of the penis with the veins occurs through apertures two or three millimètres—in. 0·117—in diameter.

In their course towards the heart, particularly in the extremities, the veins are divided into two planes;—one subcutaneous or superficial; the other deep-seated, and accompanying the deep-seated arteries.

[1] Précis, &c., ii. 238.

Numerous anastomoses occur between these, especially when the veins become small, or are more distant from the heart. We find, that their disposition differs according to the organ. In the brain, they constitute, in great part, the pia mater; and enter the ventricles, where they contribute to the formation of the plexus choroides and tela choroidea. On leaving the organ we find them situate between the laminæ of the dura mater; when they take the name of *sinuses*. In the spermatic cord, they are extremely tortuous; anastomose repeatedly, and form the *corpus pampiniforme;* around the vagina, they constitute the *corpus retiforme;* in the uterus, the *uterine sinuses.* They have three coats in superposition, according to most anatomists: but many modern anatomists are disposed to assign them six. The *outer coat* is areolar; dense, and very difficult to rupture. The *middle coat* has been termed the *proper membrane* of the veins. The generality of anatomists describe it as composed of longitudinal fibres, which are more distinct in the vena cava inferior than in the vena cava superior; in the superficial veins than in the deep-seated; in the branches than in the trunks. M. Magendie[1] states, that he has never been able to observe the fibres of the middle coat; but has always seen a multitude of filaments interlacing in all directions; and assuming the appearance of longitudinal fibres, when the vein is folded or wrinkled longitudinally, which is frequently the case in the large veins. It exhibits no signs of muscularity; even when the galvanic stimulus is applied; yet M. Magendie suspects its chemical nature to be fibrinous. It was remarked, in an early part of this work (vol. i. p. 58), that the bases of the areolar and muscular tissue are, respectively, gelatin, and fibrin; and that the various resisting solids may all be brought to one or other of those tissues. The middle coat of the veins doubtless belongs essentially to the former, and is a variety of the *tissu jaune* of the French anatomists. M. Magendie merely states its fibrinous nature to be a suspicion; and, like numerous suspicions, this may be devoid of foundation. Yet we have reason to believe, that it is contractile; and, of late,[2] it has been described as formed of one or two or even more layers between the external and internal coats; these layers consisting of fibres, which agree, in all respects, with the white areolar tissue; and are either quite pure, or mixed in one or other of the layers with a greater or less amount of fibres, resembling those of the middle coat of the arteries in having the anatomical characters of the nonstriated or unstriped muscular fibres. M. Broussais[3] affirms, that its contraction is one of the principal causes of the return of the blood to the heart. He conceives, that the alternate movements of contraction and relaxation are altogether similar to those of the heart; but that they are so slight as not to have been rendered perceptible in the majority of the veins, although they are very visible in the vena cava of frogs, where it joins the right auricle. In some experiments by M. Sarlandière

[1] Op. cit., ii. 242. See, on the researches of recent histologists, Mr. Paget, Brit. and For. Med. Review, July, 1842, ii. p. 242.

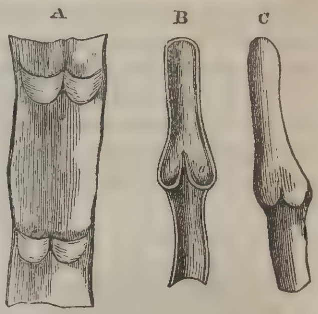
[2] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit., by Leidy, i. 518, Philad., 1849.

[3] Op. citat., American translation, p. 391.

on the circulation, he observed these movements to be independent of those of the heart. After the organ was removed, and even after blood had ceased to flow,[1] the contraction and relaxation of the vein continued for many minutes in the cut extremity.

The *inner coat* is extremely thin and smooth at its inner surface, and has an epithelial lining. It is very extensible, and yet presents considerable resistance; bearing a very tight ligature without being ruptured. In many of the veins, parabolic folds of the inner coat exist, like those in the lymphatics, which are inservient to a similar purpose; the free edge of these *valves* is directed towards the centre of the circulation, showing that their office is to permit the blood to flow in that direction, and prevent its retrogression. They do not seem, however, in many cases, well adapted for the purpose; inasmuch as their size is insufficient to obliterate the cavity of the vein. By most anatomists, this arrangement is considered to depend upon primary organization; but Bichat conceives it to be wholly owing to the state of contraction, or dilatation of the veins, at the moment of death. M. Magendie affirms, that he has never seen the distension of the veins exert any influence on the size of the valves; but that their shape is somewhat modified by the state of contraction or dilatation; and this he thinks probably misled Bichat.[2] Moreover, they are covered by the epithelial coat and consist of tissue like that of fibrous membrane, which, as Mr. Hunter[3] observed, shows, that they are not duplicatures of the lining membrane. Their number varies in different veins. As a general rule, they are more numerous, where the blood proceeds against its gravity, or where the veins are very extensible, and receive but a feeble support from the circumambient parts, as in the extremities. They are entirely wanting in the veins of the deep-seated viscera; in those of the brain and spinal marrow, and of the lungs; in the vena portæ, and in the veins of the kidneys, bladder, and uterus. They exist, however, in the spermatic veins; and, sometimes, in the internal mammary, and in the branches of the vena azygos. On the cardiac side of these valves, cavities or sinuses exist, which appear externally in the form of varices. These dilatations enable the refluent blood to catch the free edges of the valves, and thus depress them, so as to close the cavity of the vessel; serving, in this respect, precisely the same functions as the sinuses of the pulmonary artery and aorta serve in regard to the semilunar valves. The valves exist in veins of less than a line in diameter.

Fig. 288.



Diagrams showing Valves of Veins.

A. Part of a vein laid open and spread out, with two pairs of valves. B. Longitudinal section of a vein, showing the apposition of the edges of the valves in their closed state. C. Portion of a distended vein, exhibiting a swelling in the situation of a pair of valves.

[1] See, on this subject, the remarks on the *Circulation in the veins.*

[2] Précis, &c., ii. 241.

[3] Treatise on the Blood, &c., by Palmer, Amer. edit., p. 216, Philad., 1840.

The three coats united form a solid vessel,—which, according to Bichat, is devoid of elasticity, but in the opinion of M. Magendie[1] elastic in an eminent degree. The elasticity is certainly much less than in the arteries. The veins are nourished by *vasa vasorum*, or by small arteries, that have their accompanying veins. Every vessel, indeed, in the body, if we may judge from analogy, draws its nutriment, not from the blood circulating in it, but from small arterial vessels, hence termed *vasa vasorum*. This applies not only to the veins, but to the arteries. The heart, for example, is not nourished by the fluid constantly passing through it; but by vessels, which arise from the aorta, and are distributed over its surface, and in its intimate texture. The coronary arteries and their corresponding veins are, consequently, the *vasa vasorum* of the heart. In like manner, the aorta and all its branches, as well as the veins, receive their vasa vasorum. There must, however, be a term to this; and if our powers of observation were sufficient we ought to be able to discover a vessel, that must derive its support or nourishment exclusively from its own stores.

The nerves that have been detected on the veins are branches of the great sympathetic.

The capacity of the venous system is generally esteemed to be double that of the arterial. It is obvious, however, that we can only arrive at an approximation, and that not a very close one. The size and number of the veins are generally so much greater than those of the corresponding arteries, that when the vessels of a membranous part are injected, the veins are observed to form a plexus, and, in a great measure, to conceal the arteries: in the intestines, the number is more nearly equal. The difficulty of arriving at any exact conclusion regarding the relative capacities of the two systems is forcibly indicated by the fact, that whilst Borelli conceived the preponderance in favour of the veins to be as four to one, Sauvages estimated it at nine to four; Haller at sixteen to nine; and Keill at twenty-five to nine.[2] The ratio between the capacity of individual arteries and veins, is very different in different parts. Between the carotid and internal jugular it is as 196 to 441; the subclavian artery and vein, 3844 to 7396; the aorta and venæ cavæ, 9 to 16; and between the splenic artery and vein, 136 to 676.

Fig. 289.

Roots, Trunk, and Divisions of the Vena Portæ.

1, 1. Veins coming from intestines. 2. Trunk of vena portæ. 3, 3. Branches distributed in the liver.

There is one portion of the venous system, to which allusion has already been made, that is peculiar:—the *abdominal*

[1] Précis, &c., ii. 243.

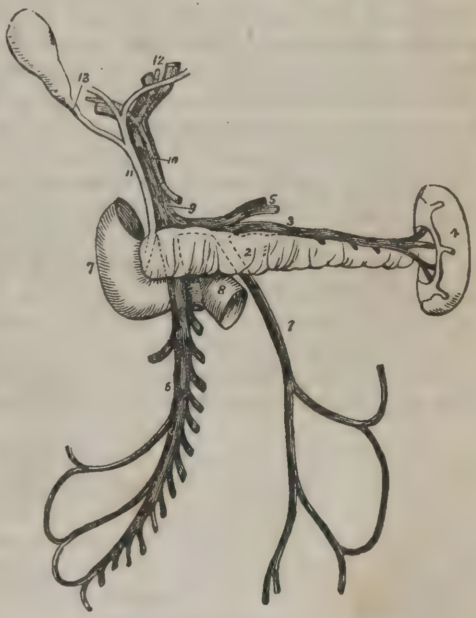
[2] Elementa Physiologiæ, lib. ii., sect. 2, § 10, Lausann., 1757.

venous or *portal system.* All the veins, that return from the digestive organs situate in the abdomen unite into a large trunk called *vena portæ.* This, instead of passing into a larger vein—into the vena cava, for example—proceeds to the liver, and ramifies, like an artery, in its substance. From the liver other veins, called *supra-hepatic*, arise, which empty themselves into the vena cavæ; and correspond to the branches of the hepatic artery as well as to those of the vena portæ. The portal system is concerned only with the veins of the digestive organs situate in the abdomen; as the spleen, pancreas, stomach, intestines, and omenta. The veins of all the other abdominal organs,—of the kidney, suprarenal capsules, &c., are not connected with it. The first part of the vena portæ is called, by some authors, *vena portæ abdominalis* seu *ventralis* to distinguish it from the hepatic portion, which is of great size, and has been called *sinus* of the vena portæ.

2. BLOOD.

It is not easy to ascertain the total quantity of blood circulating in both arteries and veins. Many attempts have been instituted for this purpose, but the statements are most diversified, partly owing to the erroneous direction followed by experimenters, but, still more, to the variation that must be perpetually occurring in the amount of fluid, according to age, sex, temperament, activity of secretion, &c. Harvey and the earlier experimenters formed their estimates by opening the veins and arteries freely on a living animal, collecting the blood that flowed, and comparing this with the weight of the body. The plan is, however, objectionable, as the whole of the blood can never be obtained in this manner, and the proportion discharged varies in different animals and circumstances. By this method, Moulins found the proportion in a sheep to be $\frac{1}{23}$d; King, in a lamb, $\frac{1}{20}$th; in a duck, $\frac{1}{30}$th; and in a rabbit $\frac{1}{30}$th. From these and other observations, Harvey concluded, that the weight of the blood of an animal

Fig. 290.



Portal System.

1. Inferior mesenteric vein: traced by means of dotted lines behind the pancreas (2) to terminate in splenic vein (3). 4. Spleen. 5. Gastric veins, opening into splenic vein. 6. Superior mesenteric vein. 7. Descending portion of duodenum. 8. Its transverse portion which is crossed by superior mesenteric vein and by a part of trunk of superior mesenteric artery. 9. Portal vein. 10. Hepatic artery. 11. Ductus communis choledochus. 12. Divisions of duct and vessels at transverse fissure of liver. 13. Cystic duct leading to gall-bladder. (Wilson.)

is to that of the whole animal as 1 to 20. Drélincourt, however, found the proportion in a hog to be nearly $\frac{1}{10}$th; and Moor, $\frac{1}{12}$th.[1] Sir George Lefevre[2] cites from Wrisberg, that from a plethoric young woman, who was beheaded, 25 pounds [?] of blood were collected; and some recent experiments by Mr. Wanner led to the following results: A bullock, weighing 1659 pounds imperial, yielded 69 pounds of blood, or in the ratio of 1 to 23·81; another weighing 1640 pounds, yielded 65 pounds, or in the ratio of 1 to 23·73; a cow, weighing 1293 pounds, yielded 59 pounds, or as 1 to 21·77; a sheep, weighing 110 pounds, yielded $5\frac{1}{2}$ pounds, or in the proportion of 1 to 22·72; another weighing 88 pounds, yielded 4·4 pounds, or as 1 to 20; and in a rabbit, the proportion was as 1 to 25 exactly.

An animal, according to Sir Astley Cooper,[4] generally expires, as soon as blood, equal to about $\frac{1}{16}$th of the weight of the body, is abstracted. Thus, if it weighs sixteen ounces, the loss of an ounce of blood will be sufficient to destroy it; and, on examining the body, blood will still be found—in the small vessels especially—even although every facility may have been afforded for draining them. Experiments have, however, shown that no fixed proportion of the circulating fluid can be indicated as necessary for the maintenance of life. In the experiments of Rosa, asphyxia occurred in young calves when from three to six pounds, or from $\frac{1}{32}$d to $\frac{1}{20}$th of their weight, had been abstracted; but in older ones not until they had lost from twelve to sixteen pounds, or from $\frac{1}{11}$th to $\frac{1}{9}$th of their weight. In a lamb, asphyxia supervened on a loss of twenty-eight ounces, or $\frac{1}{28}$th of its weight; and in a wether, on a loss of sixty-one ounces, or $\frac{1}{23}$d of its weight. Dr. Blundell[5] found that some dogs died after losing nine ounces, or $\frac{1}{30}$th of their weight; whilst others withstood the abstraction of a pound, or $\frac{1}{10}$th of their weight; and M. Piorry affirms, that dogs can bear the loss of $\frac{1}{25}$th of their weight, but if a few ounces more be drawn they succumb. From all the experiments and observations, Burdach[6] concludes, that, on the average, death occurs when $\frac{3}{4}$ths, or $\frac{7}{8}$ths, of the mass of blood is lost, although he has observed it in many cases, as in hæmoptysis, on the loss of $\frac{1}{4}$th, and even of $\frac{1}{8}$th.

The following table exhibits the computations of different physiologists regarding the weight of the circulating fluid—arterial and venous.

	lbs.		lbs.
Harvey, Lister, Moulins, Abildguard,	8	Müller and Burdach,	20
Blumenbach, Lobb, Lower,	10	Wagner,	20 to 25
Sprengel,	10 to 15	Quesnai,	27
Günther,	15 to 20	F. Hoffmann,	28
		Haller,	28 to 30
		Young,	40
		Hamberger,	80
		Keill,	100

Although the absolute estimate of Hoffmann has been regarded as

[1] Haller, op. cit., lib. v. sect. 1, § 2.
[2] An Apology for the Nerves, p. 30, London, 1844.
[3] Edinburgh Med. and Surg. Journ., July, 1845.
[4] Principles and Practice of Surgery, p. 33, Lee's edition, Lond., 1836.
[5] Researches, Physiological and Pathological, pp. 66 and 94, Lond., 1825.
[6] Die Physiologie als Erfahrungswissenschaft, iv. 101 and 334, Leipzig, 1832.

below the truth, the proportion has seemed to be nearly accurate. He conceives, that the weight of the blood is to that of the whole body as 1 to 5. Accordingly, an individual weighing one hundred and fifty pounds, will have about thirty pounds of blood; one of two hundred pounds, forty; and so on. Of this, one-third is supposed to be contained in the arteries, and two-thirds in the veins. The estimate of Haller[1] is, perhaps, near the truth; the arterial blood being, he conceives, to the venous, as 4 to 9. Were we, therefore, to assume that the whole quantity of the blood is thirty pounds in a man weighing one hundred and fifty pounds, which is perhaps allowing too much,—nine pounds, at least, may be contained in the arteries, and the remainder in the veins.

An ingenious plan, proposed by Valentin[2] for estimating the quantity of blood in the body, affords an approximation to the truth, and is confirmatory of the estimate made from other data. Having weighed an animal, and determined the proportion of solid matter in a portion of its blood, he injects into its vessels a given quantity of distilled water, which soon becomes mixed with the blood. He then takes away a fresh portion of blood, and ascertains the proportion of solid matter in it. The relation between the amount of solid matter in the blood first taken, and that in the blood diluted with the given quantity of water, enables him to calculate the quantity of blood in the body of the animal. The following question and solution are given, in order to show, how the quantity of blood may be estimated in the manner proposed by Valentin.

A portion of blood, (=1190 grains,) drawn from a dog, yielded 24·54 per cent. of solid matter. After injecting 10,905 grains of water into the bloodvessels, a portion of blood drawn yielded 21·86 (or, by another trial, 21·89) per cent. of solid matter. What was the amount of blood in the body at the commencement of the experiment?

Let x be the amount of blood *after* the first experiment. Then, since it contained 24·54 per cent. of solid residue, the amount of solid matter in it was $\cdot 2454\,x$.

After injecting the water the whole amount of the diluted blood was $x + 10905$; and, (by the experiment,) the solid matter which it contained was $= \cdot 2186\,(x + 10905)$. But the solid matter was of the same amount in both cases. Therefore we have,

$$\cdot 2454\,x = \cdot 2186\,(x + 10905)$$

$$\text{or,} \quad (\cdot 2454 - \cdot 2186)\,x = \cdot 2186 \times 10905$$

$$\text{or,} \quad x = \frac{2383\cdot 8330}{\cdot 0268} = 88945 \text{ grs.}$$

Add for the blood first drawn - - - - 1190

And we get - - - - - - - - 90135 grs.

the weight of blood in the body, at the commencement of the experiment.

The ratio 21·89 per cent. gives - - - 91269 grs.

And the mean of the two is - - - - 90702 "

[1] Op. cit., lib. v. sect. 1, § 3.

[2] Lehrbuch der Physiologie des Menschen, i. 490, Braunschweig, 1844.

In this manner, Valentin found the ratio of blood to the weight of the body to be in the dog as 1 to 4·36 in the male sex, and 1 to 4·93 in the female; and adapting these proportions to M. Quetelet's table of the weight of the human subject at different ages, he infers, that the mean quantity of blood in the male adult, at the time when the weight of the body may be presumed to be greatest, namely, at 30 years, should be about 34½ pounds; and that of the female at 50, when the weight is generally greatest, at about 26 pounds. It is difficult, however, to believe, that there is not some fallacy in these calculations. The proportion of blood to the rest of the body, judging from the quantity that has usually flowed from animals bled to death, and the apparent quantity remaining in the vessels, seems to be excessive; and such is the view of Professor Blake of Saint Louis. In a recent letter to the author, he refers to experiments instituted by him, which consisted in injecting a weighed quantity of sulphate of alumina into the veins, and analyzing a weighed portion of the blood. As the salt had time to be well mixed with the blood before the animal died, such an analysis, he conceived, would enable the whole quantity of blood with which the salt had been mixed to be determined. The only error which—it appeared to him—might arise would be from a portion of the salt having combined with some of the tissues, or having been rapidly excreted, which could only affect the result in one direction, viz. in furnishing a greater quantity of blood than really exists. The results led Dr. Blake to infer, that there was no such source of error, as he found by this method, that the weight of blood in the body of a dog does not amount to more than between one-eighth or one-ninth part of the weight of the animal, a ratio much lower—as has been shown—than is generally conceived. "That this, however, is nearer the truth is probable from the consideration of the velocity of the circulation and the capacity of the heart, as, on the generally received opinion of the quantity of the blood, it is difficult to imagine how it can circulate so rapidly."[1] This estimate would give the quantity of blood in a man weighing 150 pounds from 16½ lbs. to 18¾—not very far from the recent estimate of Günther[2]—which is from 15 to 20 pounds.

The blood strongly resembles the chyle in properties;—the great difference consisting in the colour. The venous blood, the chyle, and the lymph become equally converted into the same fluid—arterial blood—in the lungs: both the chyle and lymph may, indeed, be regarded as rudimental blood.

Venous blood, which chiefly concerns us at present, is contained in all the veins, in the right side of the heart, and in the pulmonary artery;—organs which constitute the apparatus of venous circulation. As drawn from the arm its appearance is familiar to every one. At first, it seems to be entirely homogeneous; but, after resting for some time, separates into different portions. The colour of venous blood is much darker than that of arterial; so dark, indeed, as to have led to the epithet *black blood* applied to it. Its smell is faint and peculiar; by

[1] Medical Examiner, August, 1849, p. 459.
[2] Lehrbuch der Physiologie des Menschen, ii. Band. 1 Abtheilung. s. 122, Leipzig, 1848.

some compared to a fragrant garlic odour, but *sui generis;* its taste is slightly saline, and also peculiar. It is viscid to the touch; coagulable; and its temperature has been estimated at 96° Fahrenheit; simply, we believe, on the authority of the inventor of the thermometric scale, who marked 96° as blood heat. This is too low by at least three or four degrees. Rudolphi,[1] and the German writers in general, estimate it at 29° of Réaumur, or "from 98° to 100° of Fahrenheit;" whilst, by the French writers in general, its mean temperature is stated at 31° of Réaumur, or 102° of Fahrenheit; M. Magendie,[2] who is usually very accurate, fixes the temperature of venous blood at 31° of Réaumur, or 102° of Fahrenheit; and that of arterial blood at 32° of Réaumur, or 104° of Fahrenheit. 100° may perhaps be taken as the average. This was the natural temperature of the stomach in the case related by Dr. Beaumont,[3] which has been so often referred to in these pages. In many animals, the temperature is considerably higher. In the sheep it is 102° or 103°; but it is most elevated in birds. In the duck, it is 107°. On this subject, however, further information will be given under the head of CALORIFICATION.

The specific gravity of blood is differently estimated by different observers. Hence it is probable, that it varies in individuals, and in the same individual at different periods. Compared with water, the mean has been estimated, by some, to be as 1·0527; by others, as 1·0800, to 1·0000. It is stated, however, to have been found as high as 1·126; and, in disease, as low as 1·022. It has, moreover, been conceived, that the effect of disease is, invariably, to make it lighter; and that the more healthy the individual, the greater is its specific gravity; but our information on this point is vague. That it is not always the same in health, is proved by the discrepancy of observers. Boyle estimated it to be 1·041; Martine, 1·045; Jurin, 1·054; Muschenbroek, 1·056; Denis, 1·059; Sénac, 1·082; Berzelius, from 1·052 to 1·126; J. Müller, from 1·0527 to 1·0570; Mandl, from 1·050 to 1·059; and Dr. G. O. Rees, from 1·057 to 1·060. In a large number of experiments made upon the blood of man, the ox, and horse, M. Simon[4] found it to be between 1·051 and 1·058. The average was 1·042, which, he says, corresponds very nearly with the statement of Berzelius. The average may perhaps be 1·050. Nasse says 1·055; Zimmerman, 1·056. A part of the discrepancy may be owing to the specific gravity not having been always taken at the same temperature. Dr. B. Babington found experimentally, that four degrees of temperature corresponded with a difference of ·001 of specific weight; consequently, if one author states the specific gravity of blood at about its circulating temperature—say 98° of Fahr.—while another states it at 60° Fahr.—the usual standard—the former will make it ·0095 lighter than the latter.

The blood of man is thicker, and at least one-thousandth heavier than that of woman.

[1] Grundriss der Physiologie, i. 143, Berlin, 1821.
[2] Précis, &c., ii. 229.
[3] Experiments, &c., on the Gastric Juice, &c., p. 274, Plattsburg, 1833.
[4] Animal Chemistry, Sydenham edition, p. 100, Lond., 1845.

When blood is examined with a microscope of high magnifying power, it appears to be composed of numerous, minute, *red particles* or *corpuscles*,—commonly called *red globules*, *blood corpuscles*, and *blood disks*,—suspended in the serum. These corpuscles have a different shape and dimension, according to the nature of the animal. In the mammalia, they are circular; and, in birds and cold-blooded animals, elliptical. In all animals, they are affirmed, by some observers, to be flattened, and marked in the centre with a luminous point, of a shape analogous to the general shape of the corpuscle. Professor Giacomoni,[1] of Padua, has, however, affirmed, that the red corpuscles swimming in serum,—which have been described, by so many writers, in the circulating fluid,—exist only in the imagination. As in every case that rests on microscopic observation, the greatest discrepancy prevails, not only as regards the shape, but the size of the corpuscles. These were first noticed by Malpighi;[2] and afterwards more minutely examined by Leeuenhoek, who at first described them correctly enough in general terms; but subsequently became hypothetical; and advanced the fantasy, that the red corpuscles are composed of a series of globular bodies, descending in regular gradations; each of the red corpuscles being composed of six particles of serum; a particle of serum of six particles of lymph, &c. Totally devoid of foundation as the whole notion was, it was believed for a considerable period, even until the time when Haller wrote. Mr. Hewson[3] described the corpuscles as consisting of a solid centre, surrounded by a vesicle, filled with a fluid; and to be "as flat as a guinea." Mr. Hunter,[4] on the other hand, did not regard them as solid bodies, but as liquids possessing a central attraction that determines their shape. Della Torre[5] supposed them to be a kind of disk or ring, pierced in the centre; whilst Dr. Monro conceived them to be circular, flattened bodies, like coins, with a dark spot in the centre, which he thought was not owing to a perforation, as Della Torre had imagined, but to a depression. Cavallo,[6] again, conceived, that all these appearances are deceptive, depending upon the peculiar modification of the rays of light, as affected by the form of the particle; and he concluded, that they are simple spheres. Amici found them of two kinds; both with angular margins; but, in the one, the centre was depressed on both sides; whilst, in the other, it was elevated. The observations of Dr.

Fig. 291.

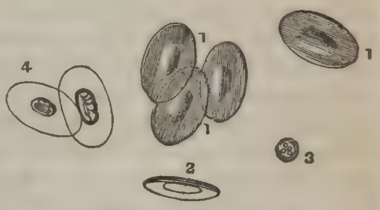
Red Corpuscles of Human Blood.

Represented at *a*, as they are seen when rather *beyond* the focus of the microscope; and at *b* as they appear when *within* the focus. Magnified 400 diameters. (Donné.)

[1] Encyclogr. des Sciences Médicales, Avril, 1840, p. 529.
[2] Opera, Lond., 1687.
[3] Experimental Inquiries, part. iii. p. 16, Lond., 1777, or Hewson's Works, by Gulliver, Sydenham Society's edit., p. 215, Lond., 1846.
[4] On the Blood, &c., by Palmer, Amer. edit., p. 63, Philad., 1840.
[5] Philos. Trans. for 1765, p. 252.
[6] An Essay on the Medicinal Properties of Factitious Air, &c., p. 237, Lond., 1798.

Young,[1] of Sir Everard Home and Mr. Bauer,[2] and of MM. Prévost and Dumas,[3] accord chiefly with those of Mr. Hewson. All these gentlemen consider the red corpuscles to be composed of a central globule, which is transparent and whitish; and of a red envelope, which is less transparent. Dr. Hodgkin and Mr. Lister[4] have denied that they are spherical, and consist of a central nucleus enclosed in a vesicle. They affirm, on the authority of a microscope, which, on comparison, was found equal to a celebrated one, taken a few years ago to Great Britain by Professor Amici,[5] that the particles of human blood appear to consist of circular, flattened, transparent cakes, their thickness being about $\frac{1}{45}$th part of their diameter. These, when seen singly, appear to be nearly or quite colourless. Their edges are rounded, and being the thickest part, occasion a depression in the middle, which exists on both surfaces. The view of these gentlemen, consequently, appears to resemble that of Dr. Monro.

Fig. 292.



Blood Corpuscles of Rana Esculenta.

1, 1, 1, 2. Blood corpuscles. 2. Seen edgewise. 3. Lymph corpuscle. 4. Altered by dilute acetic acid. (Wagner.)

Mr. Gulliver,[6] however, thinks that the ratio of 1 to 45, given by Dr. Hodgkin and Mr. Lister, must be a misprint. From measurements of the thickness, at the circumference of the corpuscles of several mammalia, he found it to be generally one-third and one-fourth the diameter: the average thickness of the human blood corpuscle he estimates at $\frac{1}{12400}$th of an English inch, and the diameter at $\frac{1}{3200}$th.

Amidst this discordance, it is difficult to know which view to adopt. The belief in their consisting of circular, flattened, transparent bodies, with a depression in the centre, and of an external envelope and a central nucleus, the former of which is red and gives colour to the blood, has had, perhaps, the greatest weight of authority in its favour. The nucleus has appeared to be devoid of colour, and to be independent of the envelope; as, when the latter is destroyed, the central portion preserves its original shape. The nucleus is much smaller than the envelope, being, according to Dr. Young, only about one-third the length, and one-half the breadth of the entire corpuscle. According to Sir Everard Home,[7] the corpuscles, enveloped in the colouring matter, are $\frac{1}{1700}$th part of an inch in diameter, requiring 2,890,000 to a square inch; but deprived of their colouring matter they appear to be $\frac{1}{2000}$th part of an inch in diameter, requiring 4,000,000 corpuscles to a square inch. From these measurements, the corpuscles, when devoid of colouring matter, are not quite one-fifth smaller. The views of MM. Prévost and Dumas, who have investigated the subject with extreme care and

[1] Introduct. to Med. Literature, p. 545.
[2] Philosoph. Transact. for 1811–1818; and Lectures on Comp. Anat., iii. 4, Lond., 1823.
[3] Annales de Chimie, &c., xxiii. 50, 90; and Journal of Science and Arts, xvi. 115.
[4] Philosoph. Magazine and Annals of Philosophy, ii. 130, Lond., 1827.
[5] Edinb. Medical and Surgical Journal, xvi. 120.
[6] Hewson's Works, Sydenham Society's edit., note to page 215, Lond., 1846.
[7] Lectures on Comparative Anatomy, iii. 4, and v. 100, Lond., 1828.

signal ingenuity, are deserving of great attention. They conceive the blood to consist essentially of serum, in which a quantity of red corpuscles is suspended; that each of these corpuscles consists of an external red vesicle, which encloses, in its centre, a colourless globule; that during the progress of coagulation, the vesicle bursts, and permits the central globule to escape; that, on losing their envelope, the central globules are attracted together; that they are disposed to arrange themselves in lines and fibres; that these fibres form a network, in the meshes of which they mechanically entangle a quantity of both the serum and the colouring matter; that these latter substances may be removed by draining, and by ablution in water; that, when this is done, there remains only pure fibrin; and that, consequently, fibrin consists of an aggregation of the central globules of the red corpuscles, while the general mass, that constitutes the crassamentum or clot, is composed of the entire particle. So far this seems satisfactory; but, we have seen, Dr. Hodgkin does not recognise the existence of external vesicle, or central nucleus; and he affirms, contrary to the notion of Sir Everard Home and others, that the particles are disposed to coalesce in their entire state. This is best seen when the blood is viewed between two slips of glass. Under such circumstances, the following appearances are distinctly perceptible. When human blood, or that of any other animal which has circular corpuscles, is examined in this manner, considerable agitation is, at first, seen to take place among the corpuscles; but, as this subsides, they apply themselves to each other by their broad surfaces, and form piles or rouleaux, sometimes of considerable length. These rouleaux often again combine,—the end of one being attached to the side of another,—so as to produce, at times, very curious ramifications. (See Fig. 295, *b*.)

The belief in the corpuscles being flattened disks is now generally admitted;—but the form of the disk is found to be altered by various substances. Its external envelope readily admits the endosmose of fluids; so that, if placed in water, it may assume a truly globular shape. In examining the blood, consequently, it is advisable to dilute it with a fluid of as nearly as possible the same character as the serum. In the particles of the blood of the frog—as represented in Fig. 292—a nucleus is observed projecting somewhat from the central portion: this is rendered extremely distinct by the action of acetic acid, which dissolves the rest of the particle, and renders the nucleus more opaque. It then appears to consist of a granular substance.

The vesicular character of the red corpuscles has been clearly shown by Dr. G. O. Rees,[1] by the readiness with which they become collapsed or distended by increasing or diminishing the specific gravity of the medium in which they float. In order to collapse the corpuscles, a solution of sp. gr. 1·060 is sufficient, but a solution of 1·070 or more is required to produce a decided effect. Solutions cease to distend the corpuscles when of sp. gr. 1·050 to 1·055, and to distend them well a solution of 1·015 or 1·010 is desirable. He has, moreover, established,

[1] Ranking's Half-Yearly Abstract of the Medical Sciences, vol. i., Jan. to June, 1845, p. 250.

that the red colouring matter of the corpuscle is seated, not in the envelope, but in the fluid within the vesicle, and that the envelopes themselves are white and colourless membranes. This is shown by increasing the specific gravity of the liquid in which the corpuscles float, the result of which is the escape by exosmose of the red coloured fluid from within the corpuscles; and, again, by applying water to the corpuscles, and inducing endosmose, the vesicles become distended and burst; their colouring matter mixes with the water, and the envelopes subside to the bottom of the vessel, forming a white layer. The red corpuscles of man have no nuclei, and their contents are probably homogeneous. They appear so at least when their surfaces are flat or slightly convex; but when concave the unequal refraction of transmitted light gives the appearance of a central spot, which is brighter or darker than the border according as it is viewed in or out of focus.[1] (See Fig. 291.)

Microscopical discordances are no less evidenced by the estimates, which have been made of the size of the red corpuscles; yet all are adduced on the faith of positive admeasurements. Leaving out of view the older, and, consequently, it might be presumed, less accurate observations, the following table shows their diameter in human blood, on the authority of some of the most eminent microscopic observers of modern times.

Sir E. Home and Mr. Bauer, with colouring matter, - - - -	$\frac{1}{1700}$th part of an inch.
Eller, - - - -	$\frac{1}{1930}$
Sir E. Home and Mr. Bauer, without colouring matter, - - -	$\frac{1}{2000}$
Müller, - - -	$\frac{1}{2300}$ to $\frac{1}{3500}$
Mandl, - - - -	$\frac{1}{2625}$ to $\frac{1}{3150}$
Hodgkin, Lister, and Rudolphi, -	$\frac{1}{3000}$
Sprengel, - - - -	$\frac{1}{3000}$ to $\frac{1}{3500}$
Cavallo, - - - -	$\frac{1}{3000}$ to $\frac{1}{4000}$
Donné, - - - -	$\frac{1}{3150}$ to $\frac{1}{3280}$
Jurin and Gulliver, - - -	$\frac{1}{3240}$
Blumenbach and Sénac, - -	$\frac{1}{3330}$
Tabor, - - - - -	$\frac{1}{3600}$
Milne Edwards, - - -	$\frac{1}{3900}$
Wagner, - - - -	$\frac{1}{4000}$
Kater, - - - -	$\frac{1}{4000}$ to $\frac{1}{6000}$
Prévost and Dumas, - - -	$\frac{1}{4056}$
Haller, Wollaston and Weber, -	$\frac{1}{5000}$
Young, - - - -	$\frac{1}{6060}$

The blood of different animals is found to differ greatly in the relative quantity of the red corpuscles it contains, the number seeming to bear a pretty exact ratio with the temperature of the animal. The higher the natural temperature, the greater the proportion of corpuscles; arterial always containing a much greater proportion than venous blood. In the greater part of the mammalia they have the same shape

[1] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 51, Philad., 184 .

as those of man; but their size varies greatly in different families. It would appear, from the researches of Mandl,[1] that of the mammalia the elephant has the largest, ($\frac{1}{100}$th of a millimètre,) and the ruminantia the smallest; that the family of camels is the only one, whose corpuscles are not round like those of the other mammalia, but elliptical like those of birds, reptiles, and fishes.[2]

The chemical constitution of the blood corpuscles is not definitely settled. Two proximate principles have been discovered in them—*hematosin* and *globulin—hematoglobulin* of Simon. The former, as mentioned hereafter, has been supposed to be the colouring matter. The latter, which differs from the globulin of Laënnec,—an impure hematosin mingled with some albumen,—is the main constituent of the globules, and is the same as the *blood-casein* of Simon. It has not been separated; but is presumed to differ but little in its properties from protein.

It has been supposed that the red corpuscles are formed originally in the germinal membrane of the embryo; but, throughout the remainder of existence, in the blood from the chyle. Their origin is, however, by no means settled. Normally, they are not found outside the vessels; and are manifestly, therefore, not inservient to nutrition; but connected, in all probability, as shown elsewhere, with respiration and calorification. It is not determined whether they are capable of reproduction, or possess independent life. Dr. Carpenter[3] thinks, that there can be no reasonable doubt, that they are to be regarded as nucleated cells, conformable in general character with the isolated cells that constitute the whole of the simplest plants; having each an independent life, and therefore the power of reproduction. Such too, is the view of Dr. Martin Barry and other microscopists. Wagner, Gulliver, and others,[4] from observation of the blood of the batrachia, ascribe their origin to the colourless corpuscles to be mentioned presently, which, they consider, become red blood corpuscles when fully developed; whilst Dr. Carpenter strenuously maintains, that there is an entire functional as well as structural difference between the red and the colourless corpuscles of the blood of vertebrata. Observations by Dr. G. O. Rees[5] lead him to infer, that they multiply by division. On examining a portion of blood, kept at about its natural temperature, he observed the corpuscles assume an hour-glass form, which, increasing, eventually divided each corpuscle into two unequal-sized circular bodies. These, when treated with a strong saline solution, underwent the same exosmotic changes as are observed in common blood corpuscles.

In addition to the red, white corpuscles are observed in the blood. These were noticed by Prof. Müller in that of frogs; and by M. Mandl[6]

[1] Manuel d'Anatomie Générale, p. 248, Paris, 1843. For numerous admeasurements of the red corpuscles of the blood of man and animals, see Note by Mr. Gulliver to Hewson's Works, Sydenham Society's edit., p. 237, Lond., 1846.

[2] Op. citat., and Annales des Sciences Naturelles, 1824 and 1825.

[3] Principles of Human Physiology, 2d edit., p. 499, London, 1844.

[4] V. Bruns, Lehrbuch der Physiologie des Menschen, s. 140. Braunschweig, 1841.

[5] Gulstonian Lecture; see Ranking, Half-Yearly Abstract, Jan. and July, 1845, Amer. edit., p. 251.

[6] Gazette Médicale, 1837; and Manuel d'Anatomie Générale, p. 252, Paris, 1843.

in that of the mammalia. They are small, colourless corpuscles, finely granulated; insoluble in water, and strongly refracting light. According to Mandl, they may be separated into two species,—some round, and containing two or three granules, which become more evident when they are treated with acetic acid: these are the true lymph corpuscles, described already (vol. i. p. 669); the others, generally also round; sometimes oblong; and at others irregular; the edges slightly notched; and the surface finely granulated. They appear to be composed of a multitude of small molecules, from $\frac{1}{1000}$th to $\frac{1}{1200}$th of a millimètre in diameter: some are also found single. These corpuscles are seen forming under the microscope, when blood, placed between two glasses, is attentively examined.

Fig. 293.

White Corpuscles of the Blood.

They are, in Mandl's opinion, produced by the coagulation of fibrin, and hence are called by him *fibrinous globules*. More recently, however, he has abandoned this name, "because it rests on a chemical character, that requires confirmation; and because it is not drawn from anatomical characters, which ought chiefly to fix the attention of the microscopist." He now terms them *white granulated corpuscles*.[1] These are the *globulins* of M. Donné, and are considered by him[2] to be first elements of blood corpuscles.

The white corpuscles are much less numerous than the red. In health the proportion may be as 1 to 50; but in disease it is often as high as 1 to 10.

Dr. Barry and Mr. Addison think, that the colourless corpuscles,—which have generally been regarded as lymph corpuscles,—are formed from the central portion of the blood corpuscles: they consider them to hold an intermediate position between the true red corpuscles, and the greatly modified forms of corpuscles, which, in their view, are the basis of the tissues, as well as of pus and other globules. The most probable opinion, however, is that the white corpuscles of the blood are identical with the lymph and chyle corpuscles; and all, in the opinion of Dr. Carpenter,[3] are connected with the elaboration of plastic fibrin, which must be constantly drawn off by the nutritive processes, and therefore require to be reproduced. His arguments on this head are certainly forcible. It was first observed by Wagner,[4] that whilst the colourless corpuscles are met with in the nutritious fluids of all animals that possess a distinct circulation, red corpuscles are restricted to the vertebrata. The truth of this has been confirmed by Dr. Carpenter, who infers from it, that the function of the colourless corpuscles must be of a general character, and intimately connected with the nutritious properties of the circulating fluid; whilst that of the red corpuscles must be of a limited character, being only required in one division of the animal kingdom. One of the strongest arguments, however, in favour of the function of the white corpuscles mentioned above, is the connexion between the generation of white corpuscles in the blood, and the production of fibrin in the inflammatory process. This increase is

1 Manuel d'Anatomie Générale, p. 554, Paris, 1843.
2 Cours de Microscopie, p. 86, Paris, 1845.
3 Op. cit., 2d edit., p. 506, Lond., 1844.
4 Op. cit.

evidently the result of the local inflammation, and is observed to commence before the occurrence of any constitutional phenomena. The microscopic observations of Messrs. Addison,[1] Williams,[2] Gulliver, and others, have established, that a great accumulation of white corpuscles takes place in the vessels of an inflamed part,—partly owing to an attraction of the corpuscles towards the seat of inflammation, and partly, they were satisfied, by an actual reproduction of fresh corpuscles, which must have been owing either to their own power of generating themselves, or to some change in the blastema or fluid of circulation in the part, which favoured a more abundant production. Dr. Carpenter is a believer in the first mode of production; and certainly his view, that the production of fibrin in the blood is closely connected with the developement of white corpuscles, has strong arguments in its favour. Messrs. Kirkes and Paget[3] are strong believers in the development of the human lymph or chyle corpuscle into the red corpuscle,—a belief which is not necessarily inconsistent with that which ascribes to them the production of fibrin; and the view is confirmed by the phenomena recorded by different observers. Mr. Lane, for example, found the ruddy colour of the horse's chyle due to the presence of red corpuscles; and he and Mr. Ancell observed imperfect blood corpuscles in the large lymphatics, and ascribed the rose-colour of the lymph to them. The thoracic duct of the horse, according to M. Gulliver,[4] often appears as a coloured tube from the number of these corpuscles in the chyle, which he generally found to be smaller, more irregular and less perfect in shape than the red corpuscles in the blood. Schultz and Gurlt[5] also noticed the chyle of a reddish colour from the presence of blood corpuscles, of which they suppose, with Simon of Berlin,[6] the formation to begin in the chyle; and M. Gulliver adds, that the transition of the corpuscles of the chyle or lymph into the red corpuscles of the blood, seems now to be commonly admitted in Germany; and, long ago, Mr. Hewson[7] thought "it could not be denied," that the office of

Fig. 294.

Developement of Human Lymph and Chyle Corpuscles into Red Corpuscles of Blood.

A. A lymph or white blood-corpuscle. B. The same, in process of conversion into a red corpuscle. C. A lymph corpuscle, with the cell-wall raised up round it by the action of water. D. A lymph corpuscle, from which the granules have almost all disappeared. E. A lymph corpuscle, acquiring colour; a single granule, like a nucleus, remains. F. A red corpuscle, fully developed.

[1] Med. Gazette, Dec., 1840; Jan. and March, 1841.

[2] Principles of Medicine, Amer. edit., by Dr. Clymer, pp. 214, 215, Philad., 1844.

[3] Manual of Physiology, Amer. edit., p. 67, Philad., 1849.

[4] Appendix to English edition of Gerber's Anatomy, p. 93, and Hewson' Works, Sydenham Society's edit., p. 276, Lond., 1846.

[5] Müller, Elements of Physiology, by Baly, i. 563, Lond., 1838.

[6] Animal Chemistry, Sydenham Society's edit., i. 121, Lond., 1845; or Amer. edit., Philad., 1846.

[7] Works, Sydenham Society's edit., p. 286, Lond., 1846.

the thymus and lymphatic glands is to form the central particles found in the red corpuscles. The subject, however, requires additional light.

When blood is drawn from a vessel, and left to itself, it exhales, so long as it is warm, a fetid vapour consisting of water and animal matter, of a nature not known. This vapour is what has been called *halitus* of the blood,—by Plenck, *gas animale sanguinis*, which, he conceived, is composed of carbon and hydrogen, and is inservient to many supposititious uses in the economy. The odour exhaled by the blood would appear to have the same general characters under all circumstances. After a time, the blood coagulates, giving off, at the same time, it has been said, a quantity of carbonic acid gas. This disengagement is not evident when the blood is suffered to remain exposed to the air, except, perhaps, by the apertures or canals formed by its passage through the clot; but it can be collected by placing the blood under the receiver of an air-pump, and exhausting the air. On this fact, however, observers do not all accord. The experiments of Vogel,[1] Brande,[2] Sir E. Home,[3] and Sir C. Scudamore,[4] are in favour of such evolution; and the last gentleman conceives it even to be an essential part of the process; but other distinguished experimenters have not been able to detect it. Neither Dr. John Davy,[5] nor Dr. Duncan, Jr., nor Dr. Christison, could procure it during the coagulation of the blood. Dr. Turner[6] suggests, that the appearance of the carbonic acid, in the experiments of Vogel, Brande, and Scudamore, might easily have been occasioned by casual exposure of the blood to the atmosphere, previous to its being placed under the receiver; but we have no reason for believing, that this source of fallacy was not guarded against as much by one set of experimenters as by the other. Our knowledge on this point is confined to the fact, that, by some, carbonic acid gas has been found exhaled during the process of coagulation;—by others, not. Experiments by Stromeyer,[7] Gmelin, Tiedemann, and Mitscherlich,[8] would seem to show, that the blood does not give off free carbonic acid, but that it holds a certain quantity in a state of combination; and that this combination is intimate is shown by the fact, mentioned by Müller,[9] that blood, artificially impregnated with carbonic acid, yields no appreciable quantity of the gas, when subjected to the air-pump. Magnus,[10] however, found, in his experiments, that not only venous, but arterial blood, contains carbonic acid, oxygen, and nitrogen; and that, as regards carbonic acid, arterial blood contains more than venous; and he accounts for the failure of those, who have attempted to elicit carbonic acid

[1] Annales de Chimie, t. xciii.

[2] Philosophical Transactions for 1818, p. 181.

[3] Lectures, &c., iii. 8.

[4] Philosophical Transactions for 1820, p. 6; and an Essay on the Blood, p. 107, Lond., 1824.

[5] Phil. Trans, for 1823, p. 506; and Edinb. Med. and Surg. Journ., xxix. 253. Since that time, however, Dr. Davy has succeeded in extricating it both from venous and arterial blood. See his Researches, Physiological and Anatomical, Amer. Med. Lib. edit., p. 82, Philad., 1840.

[6] Elements of Chemistry, 5th edit., by Dr. Bache, p. 607, Philad., 1835.

[7] Schweigger's Journal für Chemie, u. s. w. lxiv., 105.

[8] Tiedemann und Treviranus, Zeitschrift für Physiologie, B. v. H. i.; cited in British and Foreign Med. Review, No. 9, p. 590, April, 1836.

[9] Op. cit., p. 329.

[10] Annales de Chimie et de Physique, Nov., 1837.

from venous blood by the air-pump, to the air in the receiver not having been sufficiently rarefied. Prof. C. A. Schultz, of Berlin—who believes, that the vesicles of the blood, in a perfect state, are composed of a membranous covering, whose interior is filled with an aeriform fluid in the midst of which is found the nucleus[1]—succeeded in so evident a manner by the following simple method in extracting air from the blood, "that it is impossible to doubt there exists a great quantity of air in the vesicles." He completely filled a bottle with warm blood flowing immediately from the vein of a horse, and hermetically sealed the bottle so that the cork was plunged into the blood, thus absolutely preventing the contact of air. The blood, on cooling, diminished in volume, and thus produced a perfect vacuum in the upper part of the bottle; and in proportion as this took place, bubbles of air arose from the blood and filled the vacuum. Chemical analysis of this air demonstrated that it was carbonic acid. In arterial blood, he found oxygen mixed with more or less carbonic acid.[2] The experiments of Dr. Stevens,[3] and of Dr. Robert E. Rogers,[4] also show, that carbonic acid is contained in the blood. The latter observer found, when a portion of venous blood was placed in a bag of some membrane, and the bag was immersed in an atmosphere of gas—as of oxygen, hydrogen, or nitrogen—that carbonic acid was pretty freely evolved.[5]

Whilst the blood is circulating in the vessels, it consists of *liquor sanguinis* and red corpuscles; but during coagulation it separates into two distinct portions;—a yellowish liquid, called serum; and a red solid, known by the name of *clot*, *cruor*, *crassamentum*, *coagulum*, *placenta*, *insula* and *hepar sanguinis*. The proportion of the serum to the crassamentum varies greatly in different animals, and in the same animal at different times, according to the state of the system. The latter is more abundant in healthy, vigorous animals, than in those that have been impoverished by depletion, low living, or disease. Sir Charles Scudamore found, by taking the mean of twelve experiments, that the crassamentum amounted to 53·307 per cent. in healthy blood.

The difference between living and coagulated blood may be expressed in a tabular form as follows:—

Living Blood.	*Liquor Sanguinis,*	Water, Various salts, Fatty matters, Extractive do. Albumen,	Serum,	Coagulated Blood.
		Fibrin,	Crassamentum,	
	Red Corpuscles,			

The *serum* is viscous, transparent, of a slightly yellowish hue, and alkaline owing to the presence of a little free soda. Its smell and taste resemble those of the blood. Its average specific gravity has been estimated at about 1·027; but on this point, also, observers differ. Dr.

1 London Lancet, August 10, 1839, p. 713.
2 Ibid., p. 714.
3 Philos. Transact., for 1834–5, p. 334.
4 American Journal of the Med. Sciences, August, 1836, p. 283.
5 See, on all this subject, Dr. John Reid, art. Respiration, Cyclop. of Anat. and Physiol., Pt. xxxii. p. 359, Lond., August, 1848.

John Davy[1] found it to vary from 1·020 to 1·031. Martine, Muschenbroek, Jurin, and Haller, from 1·022 to 1·037; Berzelius and Wagner,[2] from 1·027 to 1·029; Dr. Christison,[3] from 1·029 to 1·031; Lauer,[4] from 1·009 to 1·011; whilst Mr. Thackrah[5] found the extremes to be 1·004 and 1·080. At 158° of Fahrenheit, it coagulates; forming at the same time, numerous cells, containing a fluid, which oozes out from the coagulum of the serum, and is called *serosity*. It contains, according to Dr. Bostock, about $\frac{1}{50}$th of its weight of animal matter, together with a little chloride of sodium. Of this animal matter, a portion is albumen, which may be readily coagulated by means of galvanism; but a small quantity of some other principle is present, which differs from albumen and gelatin, and to which Dr. Marcet[6] gave the name *muco-extractive matter*, and Dr. Bostock,[7] *uncoagulable matter of the blood*—as a term expressive of its most characteristic property. Serum preserves its property of coagulating, even when largely diluted with water. According to Mr. Brande,[8] it is almost pure liquid albumen, united with soda which keeps it fluid. Consequently, he affirms, any reagent, that takes away the soda, produces coagulation; and by the agency of caloric, the soda may transform a part of the albumen into mucus. The action of the galvanic pile coagulates the serum, and forms globules in it analogous to those of the blood.

From the analysis of serum, by Berzelius,[9] it appears to consist, in 1000 parts;—of water, 903; albumen, 80; substances soluble in alcohol,—as lactate of soda and extractive matter, chlorides of sodium and potassium, 10; substances soluble in water,—as soda and animal matter, and phosphate of soda, 4; loss, 3. Dr. Marcet assigns it the following composition:—water, 900 parts; albumen, 86·8; chlorides of potassium and sodium, 6·6; muco-extractive matter, 4; carbonate of soda, 1·65; sulphate of potassa, 0·35, and earthy phosphates, 0·60;—a result, which closely corresponds with that of Berzelius, who states that the *extractive matter* of Dr. Marcet is lactate of soda, united with animal matter. According to M. Lecanu,[10] 1000 parts contain,—water, 906 parts; albumen, 78; animal matter, soluble in water and alcohol, 1·69; albumen combined with soda, 2·10; crystallizable fatty matter, 1·20; oily matter, *serolin*, 1; chlorides of sodium and potassium, 6; subcarbonate and phosphate of soda, and sulphate of potassa, 2·10; phosphate of lime, magnesia and iron, with subcarbonate of lime and magnesia, 0·91; loss, 1. A very recent analysis by Scherer,[11] gives the following constituents:—

[1] Researches, Physiological and Anatomical, Amer. Med. Lib. edit, p. 11, Philad., 1840.
[2] Elements of Physiology, by R. Willis, § 103, Lond., 1842.
[3] On Granular Degeneration of the Kidneys, p. 61, Lond., 1839; or American Medical Library edition, Philad., 1839.
[4] Hecker's Annalen, xviii. 393.
[5] Inquiry into the Nature and Properties of the Blood, &c., Lond., 1819.
[6] Medico-Chirurg. Transact., ii. 364.
[7] Op. cit., p. 292.
[8] Philosoph. Transact. for 1809, p. 373.
[9] Medico-Chirurg. Transactions, iii. 231.
[10] Journal de Pharmacie, xvii.; and Annales de Chimie, &c., xlviii. 308.
[11] Canstatt und Eisenmann's Jahresbericht über die Fortschritte in der Biologie im Jahre, 1848, s. 65, Erlangen, 1849.

Water,	910·45
Fixed parts,	89·55
	1000·
Albumen,	74·15
Extractive matters,	5·96
Salts soluble in water,	8·75

Occasionally, the serum presents a whitish hue, which has given rise to the opinion that it contains chyle; but it would seem that this is fatty matter, and is always present. In the serum of the blood of spirit-drinkers, Dr. Traill found a considerable portion, which has been considered to favour the notion, that the human body may, by intemperance, become preternaturally combustible; and has been used to account for some of the strange cases of *spontaneous combustion*, or rather of *preternatural combustibility*, which are on record. Dr. Christison has likewise met with fat mechanically diffused through the serum, like oil in an emulsion. On one occasion, he procured five per cent. of fat from milky serum, and one per cent. from serum which had the aspect of whey.[1]

The *crassamentum* or *clot* is a solid mass, of a reddish-brown colour, which, when gently washed for some time under a small stream of water, separates into two portions,—colouring matter and fibrin. As soon as the blood is drawn from a vessel, the colouring matter of the red corpuscles leaves the central nucleus free; these then unite, as we have seen, and form a network, containing some of the colouring matter, and many whole corpuscles. By washing the clot in cold water, the free colouring matter and the globules can be removed, and the fibrin will alone remain. When freed from the colouring matter, the fibrin is solid, whitish, insipid, inodorous, heavier than water, and without action on vegetable colours; elastic when moist, and becoming brittle by desiccation. It yields, on distillation, much carbonate of ammonia, and a bulky coal, the ashes of which contain a considerable quantity of phosphate of lime, a little phosphate of magnesia, carbonate of lime, and carbonate of soda. One hundred parts of fibrin, according to Berzelius, consist of carbon, 53·360; oxygen, 19·685; hydrogen, 7·021; nitrogen, 19·934. Fibrin has been designated by various names: it is the *gluten*, *coagulable lymph*, and *fibre of the blood*, of different writers. Its specific gravity is said to be greater than that of serum; but the difference has not been accurately estimated, and cannot be great. The red corpuscles are manifestly, however, heavier than either, as we find them subsiding during coagulation to the lower surface of the clot, when the blood has flowed freely from the orifice in the vein. Fibrin appears to be the most important constituent of the blood. It exists in animals in which the red corpuscles are absent, and is the basis of muscular tissue.

The colouring matter of the blood, called, by some, *cruorin*, *hematin*, *hematosin*, *zoo-hematin*, *hemachroin*, *globulin* (of Lecanu), and *rubrin*, has been the subject of anxious investigation with the analytical chemist. It has been already remarked, that it resides in distinct particles or corpuscles, and in the fluid within the enveloping membrane.

[1] Edinb. Med. and Surg. Journal, xvii. 235, and xxxiii. 274.

Formerly, however, the opinion was universal, that the vesicular envelope is the seat of colour. The colouring principle is dissolved, by pure water, acids, alkalies, and alcohol. M. Raspail[1] asserts, that the corpuscles are entirely soluble in pure water, but MM. Donné and Boudet, who repeated his experiments, declare that they are wholly insoluble, and Müller[2] is of the same opinion. Great uncertainty has always existed regarding the cause of the colour of the corpuscles. As soon as the blood was found to contain iron, the peroxide of which has a red hue, their colour was ascribed to the presence of that metal. MM. Fourcroy and Vauquelin[3] held this opinion, conceiving the iron to be in the state of subphosphate; and they affirmed, that if this salt be dissolved in serum by means of an alkali, the colour of the solution is exactly like that of the blood. Berzelius,[4] however, showed, that the subphosphate of iron cannot be dissolved in serum by means of an alkali, except in very minute quantity; and that this salt, even when rendered soluble by phosphoric acid, communicates a tint quite different from that of the red corpuscles. He found, that the ashes of the colouring matter always yield oxide of iron in the proportion of $\frac{1}{200}$th of the original mass; whence it was inferred, that iron is somehow or other concerned in the production of the colour; but the experiments of Berzelius did not indicate the state in which that metal exists in the blood. He could not detect it by any of the liquid tests.

The views of Berzelius, and the experiments on which they were founded, were not supported by the researches of Mr. Brande.[5] He endeavoured to show, that the colour of the blood does not depend upon iron; for he found the indications of the presence of that metal as considerable in the parts of the blood that are devoid of colour, as in the corpuscles themselves; and in each it was present in such small quantity, that no effect, as a colouring agent, could be expected from it. He supposed that the tint of the red corpuscles is produced by a peculiar, animal colouring principle, capable of combining with metallic oxides. He succeeded in obtaining a compound of the colouring matter of the blood with the oxide of tin: but its best precipitants are the nitrate of mercury and corrosive sublimate. Woollen cloths, impregnated with either of these compounds, and dipped in an aqueous solution of the colouring matter, acquire a permanent red dye, unchangeable by washing with soap. The conclusions of Mr. Brande have been supported by M. Vauquelin,[6] but the fact of the presence of iron seems to have been decided by many observers. Engelhart[7] demonstrated, that the fibrin and albumen of the blood, when carefully separated from colouring particles, do not contain a trace of iron; whilst he procured it from the red corpuscles by incineration. He also succeeded in proving the presence of iron in the colouring matter by liquid tests; for on transmitting a current of chlorine gas through a solution of red corpuscles, the

1 Chimie Organique, p. 368, Paris, 1833.
2 Handbuch der Physiologie, Baly's translation, p. 105, Lond., 1838.
3 System. Chym., ix. 207.
4 Med. Chir. Trans., iii. 213.
5 Philosophical Transactions for 1812, p. 90.
6 Annales de Chimie et de Physique, tom. i. p. 9.
7 Edinb. Med. and Surg. Journal, Jan., 1827; and Turner's Chemistry, 5th Amer. edit., p. 605, Philad., 1835.

colour entirely disappeared; white flocks were thrown down, and a transparent solution remained, in which peroxide of iron was discovered by the usual reagents. The results, obtained by Engelhart, as regards the quantity of iron, correspond with those of Berzelius. These facts have since been confirmed by Rose,[1] of Berlin;—and Würzer,[2] of Marburg, by pursuing Engelhart's method by liquid tests, detected the existence of the protoxide of manganese likewise. The proportion of iron does not appear to be more than one-half per cent.; yet, as it is contained only in the colouring matter, there is some reason for believing, that it may be concerned in the coloration of the blood, although probably in the form of oxide. Sulphocyanic acid has been detected in the saliva; and this acid, when united with peroxide of iron, forms a colour exactly like that of venous blood; so that it has been presumed that it may be connected with the coloration of the blood; but this is not probable; for Dr. Stevens found, that venous blood is darkened by sulphocyanic acid. M. Lecanu[3] has subjected *hematosin* or the colouring matter to analysis, and found it to be composed of:—loss, representing the weight of the animal matter, 97·742; subcarbonate of soda, alkaline chlorides, subcarbonates of lime and magnesia, and phosphates of lime and magnesia, 1·724; peroxide of iron, 0·534. The result of his researches induces him to conclude, that the colouring matter is a compound of albumen with some colouring substance unknown. This substance yielded on analysis:—loss, 98·26; peroxide of iron, 1·74; and M. Lecanu suggests, that it may result from the combination of some animal matter with certain ferruginous compounds analogous to cyanides.

After all, therefore, our ignorance on this subject is still great; and all that we seem to know is, that peroxide of iron is contained in the colouring matter of the blood; but it can scarcely be the cause of the colour, for Scherer found, that the iron may be wholly dissolved by the agency of acids, and yet the animal matter, boiled afterwards in alcohol, colours the spirit deeply red. Dr. G. O. Rees,[4] however, objects to this being received as a conclusive argument against the iron being essential to the formation of the red colour.

The redness of the blood is one of its most obvious characteristics; and the change effected in the lungs as regards colour has been esteemed of eminent importance. It is no farther so, however, than as it indicates the conversion of venous into arterial blood. There is nothing essential connected with the mere coloration. In the insect, the blood is transparent; in the caterpillar, of a greenish hue; and in the internal vessels of the frog, yellowish. In man, it differs according to numerous circumstances; and the hue of the skin, which is partly dependent upon these differences, thus becomes an index of the state of individual health or disease. In *morbus cæruleus*, *cyanopathy* or *blue disease*, the whole surface is coloured blue, especially in those parts where the skin is deli-

[1] Poggendorf's Annalen, vii. 81; and Annales de Chimie, &c., xxxiv. 268.

[2] Schweigger's Journal, lviii. 481.

[3] Annales de Chimie et de Physique, xlv. 5.

[4] Gulstonian Lecture; see Ranking's Abstract, Jan. to July, 1845, p. 251, Amer. edit., New York, 1845.

cate, as in the lips; and the appearance of the jaundiced is familiar to all.

The formation of the clot, and its separation from the serum, are manifestly dependent upon the fibrin, which, by assuming the solid state, gives rise to the *coagulation* of the blood;—a phenomenon, that has occasioned much fruitless speculation and experiment; yet, if the views of M. Raspail[1] were proved to be correct, it would be sufficiently simple. The alkaline character of the blood, and the production of coagulation by a dilute acid leave no doubt, in his mind, that an alkali is the menstruum of the albumen of the blood. The alkaline matter, he thinks, is soda, but more especially ammonia, of which, he says, authors take no account; but whose different salts are evident under the microscope. Now, "the carbonic acid of the atmospheric air, and the carbonic acid, that forms in the blood by its avidity for oxygen, saturate the menstruum of the albumen, which is precipitated as a clot. The evaporation of the ammonia, and, above all, the evaporation of the water of the blood, which issues smoking from the vein, likewise set free an additional quantity of dissolved albumen, and the mass coagulates the more quickly as the blood is less aqueous."

The process of coagulation is influenced by exposure to air. Mr. Hewson affirmed, that it is promoted by such exposure, but Mr. Hunter was of an opposite opinion. If the atmospheric air be excluded,—by completely filling a bottle with recently drawn blood, and closing the orifice with a good stopper,—coagulation is retarded. Yet Sir C. Scudamore affirms, that if blood be confined within the exhausted receiver of an air-pump, coagulation is accelerated; and MM. Gmelin, Tiedemann, and Mitscherlich[2] found that, under such circumstances, both venous and arterial blood coagulated as perfectly as usual. The presence of air is certainly not essential to the process. Experiments have also been made on the effect produced by different gases on the process of coagulation; but the results have not been such as to afford much information. It is asserted, for example, by some, that it is promoted by carbonic acid; and certain other irrespirable gases; and retarded by oxygen: by others, the reverse is affirmed; whilst Sir Humphry Davy[3] and M. Schröder van der Kolk[4] inform us, that they could not perceive any difference in the period of the coagulation of venous blood, when it was exposed to nitrogen, nitrous gas, oxygen, nitrous oxide, carbonic acid, hydrocarbon, or atmospheric air.

The time, necessary for coagulation, is affected by temperature. It is promoted by warmth; retarded, but not prevented, by cold. Mr. Hewson froze blood newly drawn from a vein, and afterwards thawed it: it first became fluid, and then coagulated as usual. Hunter made a similar experiment with the like result. It is obviously, therefore, not from simple refrigeration that the blood coagulates. Sir C. Scudamore found, that blood, which begins to coagulate in four minutes and a half, in a

[1] Chimie Organique, p. 373.

[2] Tiedemann und Treviranus, Zeitschrift für Physiol., B. v. Heft i.

[3] Researches, &c., chiefly concerning nitrous oxide, p. 380, Lond., 1800; and Dr. John Davy, Researches, Physiological and Anatomical, Amer. Med. Libr. edit., p. 48, Philad., 1840.

[4] Dissert. sistens Sang. Coag. Histor., Gröning., p. 81, 1820; and Burdach, op. citat., iv. 37.

temperature of 53° Fahr., undergoes the same change in two minutes and a half at 98°; and that, which coagulates in four minutes at 98° Fahr., becomes solid in one minute at 120°. On the contrary, blood, that coagulates firmly in five minutes at 60° Fahr., remains quite fluid for twenty minutes at the temperature of 40° Fahr., and requires upwards of an hour for complete coagulation. The observations of M. Gendrin[1] were similar. As a general rule, it would seem, from those of Hewson,[2] Schröder van der Kolk,[3] and Thackrah,[4] that coagulation takes place most readily at the temperature of the body. During the coagulation, a quantity of caloric is disengaged. M. Fourcroy[5] relates an experiment, in which the thermometer rose no less than 11° during the process; but as certain experiments of Mr. Hunter[6] appeared to show, that no elevation of temperature occurred, the observation of Fourcroy was disregarded. It was, however, confirmed by experiments of Dr. Gordon,[7] of Edinburgh, in which the evolution of caloric during coagulation was rendered more manifest by moving the thermometer during the formation of the clot, first into the coagulated, and afterwards into the fluid part of the blood: he found, that by this means he could detect a difference of 6°, which continued to be manifested for twenty minutes after the process had commenced. In repeating the experiment on blood taken from a person labouring under inflammatory fever, the thermometer was found to rise 12°. Sir C. Scudamore affirms,[8] that the rate at which the blood cools is distinctly slower than it would be were no caloric evolved; and that he observed the thermometer rise one degree at the commencement of coagulation. On the other hand, Dr. John Davy,[9] Mr. Thackrah, and Schröder van der Kolk,[10] accord with Mr. Hunter in the belief, that the increase of temperature from this cause, is very slight or null, whilst M. Raspail asserts that the temperature falls.[11] *Again* we have to deplore the discordance amongst observers; and it will perhaps have struck the reader more than once, that such discordance applies as much to topics of direct observation as to those of a theoretical character. The discrepancy regarding anatomical and physical *facts*, is even more glaring than that which prevails amongst physiologists in accounting for the corporeal phenomena; a circumstance, which tends to confirm the notion promulgated by one of the most distinguished teachers of his day, (Dr. James Gregory,) that "there are more false facts in medicine, (and the remark might be extended to the collateral or accessory sciences,) than false theories."

1 Hist. Anatom. des Inflammations, ii. 426, Paris, 1826.
2 Experiment. Inquiries, i. 19, Lond., 1774, or Sydenham Society edit., Lond., 1846.
3 Op. cit., p. 48.
4 Inquiry into the Nature, &c., of the Blood, p. 38, Lond., 1819.
5 Annales de Chimie, xii. 147.
6 A Treatise on the Blood, &c., p. 27, Lond., 1794.
7 Annals of Philosophy, vol. iv. 139.
8 An Essay on the Blood, p. 68, Lond., 1824.
9 Researches, Physiological and Anatomical, Amer. Med. Libr. edit., p. 6, Philad., 1840.
10 Müller's Physiology, Baly's translation, p. 98, Lond., 1838.
11 Chimie Organique, p. 361.

There are certain substances, again, which, when added to the blood, prevent or retard its coagulation. Mr. Hewson found, that sulphate of soda, chloride of sodium, and nitrate of potassa were amongst the most powerful salts in this respect. Muriate of ammonia and a solution of potassa have the same effect. On the contrary, coagulation is promoted by alum, and by the sulphates of zinc and copper.[1] How these salts act on the fibrin, so as to prevent its particles from coming together, it is not easy to explain. But these are not the only inscrutable circumstances that concern the coagulation of the blood. Many causes of sudden death have been considered to have this result:—lightning and electricity; a blow upon the stomach; injury of the brain; bites of venomous animals; certain narcotico-acrid vegetable poisons; excessive exercise, and violent mental emotions, when they suddenly destroy, &c. Many of these affirmations, doubtless, rest on insufficient proof. For example, Sir C. Scudamore asserts that lightning has not this effect. Blood, through which electric discharges were transmitted, coagulated as quickly as that which was not electrified; and in animals killed by the discharge of a powerful galvanic battery, that in the veins was always found in a solid state. M. Mandl has summed up the results of modern experiments on the subject as follows. *First.* The alkalies—potassa, soda, and ammonia—completely prevent coagulation: lime retards it. *Secondly.* The soluble alkaline salts—combinations of soda, potassa, ammonia, magnesia, baryta and lime with carbonic, acetic, nitric, phosphoric, tartaric, citric, boracic, sulphuric and cyano-hydric acid—also the chlorides, in very small quantity—favour coagulation. On the other hand, these substances in concentrated solution retard, and even prevent it entirely. The most active salts are the carbonates; the least so, combinations of chlorine, and sulphates. 0·007 of carbonate of soda retards coagulation for several hours, whilst the sulphates do not act in the proportion of 14 per 1000. The action of a salt is more marked in proportion as it reddens more the blood; whilst combinations of chrome, chlorine and iodine do not redden it, and do not prevent its coagulation. When water is added to blood thus liquefied by a salt it coagulates again—the fibrin being precipitated. *Thirdly.* Metallic salts decompose the blood; some causing coagulation; others preventing it. *Fourthly.* Very dilute vegetable acids favour it; when a little more concentrated, they prevent it; and when highly concentrated, decompose it like the mineral acids. *Fifthly.* The action of vegetable substances has not been sufficiently studied: some affirm, for instance, that narcotics prevent coagulation; others that they favour it. The same doubt exists in regard to the action of poisons; it is generally believed, however, that they—as well as lightning, a violent discharge of electricity, the instantaneous destruction of the nervous system, &c.—prevent coagulation. *Sixthly.* Very dilute solutions of gum Arabic, sugar, albumen, milk, &c., appear to act only in a mechanical manner by preventing the approximation of the coagulated particles.

[1] Magendie, Lectures on the Blood, in Lond. Lancet, reprinted in Bell's Select Medical Library, Philad., 1839.

We shall find, hereafter, that the action of some of these agents has been considered evidence that the blood may be *killed;* and, consequently, that it is possessed of life. All the phenomena, indeed, of coagulation, inexplicable in the present state of our knowledge, have been invoked to prove this position. The preservation of the fluid state, whilst circulating in the vessels—although agitation, when it is out of the body, does not prevent its coagulation—has been regarded of itself, sufficient evidence in favour of the doctrine. Dr. Bostock,[1] indeed, asserts, that perhaps the most obvious and consistent view of the subject is, that fibrin has a natural disposition to assume the solid form, when no circumstance prevents it from exercising this inherent tendency. As it is gradually added to the blood, particle by particle, whilst that fluid is in a state of agitation in the vessels, it has no opportunity, he conceives, of concreting; but when suffered to remain at rest, either within or without the vessels, it is liable to exercise its natural tendency. It is not our intention, at present, to enter into the subject of the vitality of the blood. The general question will be considered in a subsequent part of this work. We may merely observe, that, by the generality of physiologists, the blood is presumed, either to be endowed with a principle of vitality, or to receive from the organs, with which it comes in contact, a vital impression or influence, which, together with the constant motion, counteracts its tendency to coagulation.[2] Even M. Magendie,[3]—who is unusually and properly chary in having recourse to this method of explaining the *notum per ignotius*,—affirms, that instead of referring the coagulation of the blood to any physical influence, it should be considered as essentially a vital process; or, in other words, as affording a demonstrative proof, that the blood is endowed with life;—a position, which—as will be seen hereafter—is not tenable.[4]

M. Vauquelin discovered in the blood a considerable quantity of fatty matter, of a soft consistence, which he, at first, regarded as fat; but M. Chevreul,[5] after careful investigation, declared it to be identical with the matter of the brain and nerves, and to form the singular compound of an *azoted fat*. Cholesterin has been detected in it by Gmelin,[6] and by Boudet.[7] MM. Prévost and Dumas, Ségalas, and others, have likewise demonstrated the existence of urea in the blood of animals, whose kidneys had been removed. Chemical analysis is, indeed, adding daily to our stock of information on this matter; and is exhibiting to us, that many of the substances, that compose the tissues, exist in the blood in the very state in which we meet with them there. This is signally shown by the following table by Simon[8] of the constituents found in the blood of man, and certain mammalia.

[1] Physiology, 3d edit., p. 271, Lond., 1836.
[2] J. Müller's Handbuch, u. s. w., Baly's translation, p. 97, Lond., 1838.
[3] Précis, &c., ii. 234.
[4] See vol. ii., chap. 5, on Life.
[5] Bostock's Physiology, p. 294.
[6] Chimie, iv. 1163.
[7] Journ. de Pharmacie, Paris, 1833, and Annales de Chimie, lii. 337.
[8] Animal Chemistry, Sydenham Society edit., p. 166, Lond., 1845.

	Water.
Protein compounds.	Fibrin. Albumen. Globulin.
Colouring matters.	Hematin. Hemaphæin.
Extractive matters.	Alcohol-extract. Spirit-extract. Water-extract.
Fats.	Cholesterin. Serolin. Red and white solid fats containing phosphorus. Margaric acid. Oleic acid.

	Iron (peroxide).
Salts.	Albuminate of soda. Phosphates of lime, magnesia, and soda. Sulphate of potassa. Carbonates of lime, magnesia, and soda. Chlorides of sodium and potassium. Lactate of soda. Oleate and margarate of soda.
Gases.	Oxygen. Nitrogen. Carbonic acid.
	Sulphur.
	Phosphorus.

The analyses of M. Lecanu[1] are generally regarded as among the best. Blood obtained by him from two stout healthy men was found to be composed as follows:—

Water,	780·145	785·590
Fibrin,	2·100	3 565
Albumen,	65·090	69·415
Colouring matter (globules),	133·000	119·626
Fatty crystallizable matter,	2 430	4·300
Oily matter,	1·310	2·270
Extractive matter soluble in water and alcohol,	1·790	1·920
Albumen combined with soda,	1·265	2·010
Chloride of sodium, " potassium, Carbonates, Phosphates, Sulphates of potassa and soda	8·370	7·304
Carbonates of lime and magnesia, Phosphates of lime, magnesia, and iron, Peroxide of iron,	2·100	1·414
Loss,	2·400	2·586
	100·000	100·000

On these analyses, Dr. Prout[2] has remarked, that *gelatin* is never found in the blood, nor any product of glandular secretion; and he adds, that a given weight of gelatin contains at least three or four per cent. less carbon than an equal weight of albumen. Hence, the production of gelatin from albumen, he conceives, must be a *reducing* process. We have seen, under the head of Respiration, what application he makes of these considerations.[3]

Researches on the ashes of the blood by Enderlin,[4] in the laboratory of Giessen, give the following as the quantitative analysis in 100 parts from human blood:—

Tri-basic phosphate of soda,	22·1
Chloride of sodium,	54·769
" potassium,	4·416
Sulphate of soda,	2·461
Phosphate of lime,	3·636
" magnesia,	0·769
Oxide of iron, with some phosphate of iron,	10·77

[1] Annales de Chimie et de Physique, xlviii. 308, and Journal de Pharmacie, Sept., 1831.
[2] Bridgewater Treatise, Amer edit., p. 280, Philad., 1834.
[3] For the methods of analyzing the blood, see Simon, op. cit., p. 166.
[4] Annalen der Chemie und Pharmacie, Marz und April, 1844, cited by Mr. Paget, in Brit. and For. Med. Rev., Jan., 1845, p. 255.

It has been inferred, from these analyses, that the albumen of the blood is not in the form of an albuminate of soda, nor of a combination with carbonate or bicarbonate of soda, but in combination with the alkaline tribasic phosphate, and chloride of sodium,—the former salt possessing, in a high degree, the power of dissolving protein compounds and phosphates of lime, and probably being the solvent of those constituents in the blood. Dr. John Davy,[1] however, thinks, that even admitting the accuracy of Enderlin's results, the propriety of applying them to the condition of the alkali in liquid blood may be questioned. Carbonate of soda, he observes, is decomposed when heated with phosphate of lime; and when added in small quantity to blood is not to be detected in its ashes. This may account for its not having been found there. Were the opinion, referred to, correct, an acid added to blood or its serum, after the action of the air-pump, ought not on re-exhaustion to occasion a farther disengagement of air; but Dr. Davy finds that it does. This and other results induce him to give the preference to the conclusion, that blood contains sesquicarbonate of soda.

M. Dutrochet believed, that he had formed muscular fibres from albumen by the agency of galvanism; and supposed, that the red corpuscles of the blood formed each a pair of plates, the nucleus being negative, the envelope positive; but Müller[2] has shown, that all the appearances, which he attributed to different electric properties of the blood, are explicable by the precipitation of the albumen and fibrin in consequence of the decomposition of the salts of the serum and of the oxidation of the copper wire used in the experiments,—both the decomposition of the salts and the oxidation of the copper being the usual effects of galvanic action. With the galvanometer he was unable to discover any electric current in the blood; and he perceived no variation in the needle of the multiplicator, when he inserted one wire into an artery of a living animal, and the other into a vein.

Lastly:—Interesting experiments and observations on the blood were published several years ago by Dr. Benjamin G. Babington.[3] The principal experiment was the following. He drew blood in a full stream into a glass vessel filled to the brim, from the vein of a person labouring under acute rheumatism. On close inspection, a colourless fluid was immediately perceived around the edge of the surface, and after a rest of four or five minutes, a bluish appearance was observed forming an upper layer on the blood, which was owing to the subsidence of the red corpuscles to a certain distance below the surface, and the consequent existence of a clear liquor between the plane of the corpuscles and the eye. A spoon, previously moistened with water, was now immersed into the upper layer of liquid, by a gentle depression of one border. The liquid was thus collected quite free from red corpuscles, and was found to be an opalescent, and somewhat viscid solution, perfectly homogeneous in appearance. By repeating the immersion, it was collected in quantity, and transferred to another vessel. That

[1] Proceedings of the Royal Society of Edinburgh, vol. ii. No. 26, for 1845.
[2] Handbuch, u. s. w., Baly's translation, p. 133.
[3] Med-Chirurg. Transact., vol. xvi., Part 2, Lond., 1831; and art. Blood (Morbid Conditions of the) in Cyclop. Anat. and Physiol., Lond., 1836.

which Dr. Babington employed was a bottle holding about 180 grains, of globular form, with a narrow neck and perforated glass stopper. The solution with which the globular bottle was filled, though quite homogeneous at the time it was thus collected, was found, after a time, to separate into two parts, viz., into a clot of fibrin, which had the precise form of the bottle into which it was received, and a clear serum, possessing all the usual characters of the fluid. From this experiment, Dr. Babington inferred, that buffed blood, to which we shall have to refer under another head, consists of only two constituents, red corpuscles, and a liquid to which he gives the name *liquor sanguinis*—*plasma* of Schultz—so called by him, because he esteems it to be the true nutritive and plastic portion of the blood, from which all the organs of the body are formed and nourished.

It has long been observed, that the blood of inflammation is longer in coagulating than the blood of health, and that the last portion of blood drawn from an animal coagulates quickest. The immediate cause of the buffy coat is thus explained by Dr. Babington. The blood, consisting of *liquor sanguinis* and insoluble red corpuscles, preserves its fluidity long enough to permit the corpuscles, which are of greater specific gravity, to subside through the liquor sanguinis. At length, the *liquor sanguinis* separates, by a general coagulation and contraction, into two parts; and this phenomenon takes place uniformly throughout the liquor. That part of it, through which the red corpuscles had time to fall, furnishes a pure fibrin or buffed crust, whilst the portion into which the red corpuscles had descended furnishes the coloured clot. This, in extreme cases, may be very loose at the bottom, from the great number of red corpuscles collected there, each of which has supplanted its bulk of fibrin, and consequently diminished its firmness in that part. There is, however, with this limitation, no more fibrin in one part of the blood than another. Researches by Mr. Gulliver[1] would seem to show, that the rate at which the red corpuscles sink in a fluid may give a very incorrect measure of its tenuity, since they subside much slower in serum, or in liquor sanguinis made thinner and lighter by weak saline solutions, than in the same animal fluids made thicker and heavier by gum. The blood, too, may have its coagulation retarded, whilst it is thinned and reduced in specific gravity; and yet no buffy coat appear. The greater aggregation of the corpuscles, observed by Mr. T. Wharton Jones,[2] and subsequently in his experiments, seemed to him to be connected with the accelerated rate of subsiding; as it was prevented or reversed by salts, which dispersed the corpuscles, and increased by viscid matters, which increased the aggregation. It is a well-known fact, that the shape of the vessel into which the blood is received influences the depth of the buff. The space, left by the gravitation of the red corpuscles, bears a proportion to the whole perpendicular depth of the blood, so that in a shallow vessel scarcely any buff may appear, whilst the same blood in a deep vessel would have furnished a crust of considerable thickness; but Dr. Babington asserts,

[1] Dublin Med. Press, Dec. 11, 1844.
[2] Edinburgh Med. and Surg. Journal, Oct., 1843, p. 309.

that even the quantity of the crassamentum is dependent, within certain limits, on the form of the vessel. If this be shallow, the crassamentum will be abundant; if approaching the cube or sphere in form, it will be scanty. The difference is owing to the greater or less distance of the coagulating particles of fibrin from a common centre, which causes a more or less powerful adhesion and contraction of those particles. This is a matter of practical moment, inasmuch as blood is conceived to be thick or thin, rich or poor, in reference to the quantity of crassamentum; and pathological views are entertained in consequence of conditions, which, after all, may depend not perhaps on the blood itself, but on the vessel into which it is received.

To remove an objection, that might be urged against a general conclusion deduced from the experiment cited,—that it was made upon blood in a diseased state,—Dr. Babington received healthy blood into a tall glass vessel half filled with oil, which enabled the red corpuscles to subside more quickly than would otherwise have been the case. This blood was found to have a layer of *liquor sanguinis*, which formed a buffy coat, whilst a portion of the same blood, received into a similar vessel, in which there was no oil, had no buff. Hence, it appeared, that healthy blood is similarly constituted as blood disposed to form a buffy coat, the only difference being, that the former coagulates more quickly than the latter. Dr. J. Davy,[1] however, has observed, that inflammatory blood, in some instances, does not coagulate more slowly than healthy blood, and as from the experiments of Professor Müller[2] it would appear that the presence of fibrin in the blood favours the subsidence of the red particles, Müller was led to infer, that the formation of the buffy coat may arise from the blood containing a larger quantity of fibrin, which the blood of inflammation is known to do. So that the principal causes, he thinks, of the subsidence of the red particles and the formation of the buffy coat in inflammatory blood, appear to be—the slow coagulation of the blood, and the increased quantity of fibrin. The most correct view, however, is, perhaps, that of M. Andral,[3] that the essential condition of the buffy coat is an increase in the quantity of fibrin in proportion to the red corpuscles. Hence, if there be an absolute increase of fibrin, the red corpuscles remaining the same, as in inflammation; or, if there be a diminution in the proportion of the red corpuscles, the fibrin remaining the same, as in chlorosis, the buffy coat may result; provided only there be—as there probably always is under such circumstances—a greater aggregation of the corpuscles.

An interesting fact connected with this subject has been noticed by Mr. T. Wharton Jones.[4] If a single drop of inflammatory blood be examined by the microscope, it will be seen that the red corpuscles have an unusual attraction for each other, which occasions them to coalesce in piles and masses, as in the second marginal illustration, leaving wide interspaces for the fibrin, lymph-corpuscles, and serum. It is probable, too, that there is an increased attraction between the

[1] Philosophical Transactions, for 1822. [2] Op. citat., p. 117.
[3] Hématologie Pathologique, p. 75, Paris, 73, or Meigs's and Stillé's translation, Philad., 1844.
[4] Edinburgh Medical and Surgical Journal, Oct., 1843, p. 309.

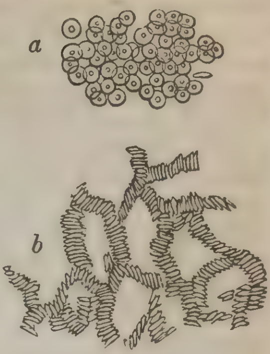
particles of the fibrin, which will account for the firmer clot of the blood of inflammation.

The fact of a single drop of blood being sufficient to indicate the character of the whole mass may be important in cases where a doubt exists as to the propriety of bleeding to any extent.

It is proper to remark, that recent researches by Mulder[1] have led him to infer, that the buffy coat does not consist of true fibrin, but is a compound of a binoxide of protein, which is insoluble in boiling water, and a tritoxide, which is soluble. These oxides Mulder comprehends under the name *oxyprotein*.

It may, also, be remarked, that in all experiments on the horse, whenever the blood flows from an opened vein in a continuous stream, with a sufficiently strong jet, and is received into a vessel that is neither too shallow nor too wide, the upper part of the clot is instantly found occupied by a white mass, which perfectly resembles the buff of the blood of man. Such was the result of the observations of MM. Andral, Gavarret, and Delafond.[2]

Fig. 295.



Aggregation of Corpuscles in Healthy and in Inflamed Blood.

a. Healthy blood. *b*. Inflamed blood.

It need scarcely be said, that venous blood, composed as it is in part of the products of heterogeneous absorption, must differ in its character in the different veins. In its passage through the capillary or intermediate circulation, the arterial blood is deprived of several of its elements, but this deprivation is different in different parts of the body. That, for example, which returns from the salivary glands, must vary from that which returns from the kidneys. In the blood of the abdominal venous system, the greatest variation is observed. Professor Schultz[3] has inquired into the chemical and physiological differences between that of the vena portæ and of the arteries and other veins. He found, that it is not reddened by the neutral salts, or by exposure to the atmosphere, or to oxygen; that it does not generally coagulate; contains less fibrin; proportionably more cruor, and less albumen; and has twice as much fat in its solid parts as that of the arteries and other veins; the proportions being as follows:—

Blood of the vena portæ	1·66 per cent.
of the arteries	0·92
of the other veins	0·83

Simon,[4] in his researches, also found a much less proportion of fibrin, and a larger of fat and of colouring matter. The fat he ascribes to the fluids produced during the act of digestion, which are conveyed into the portal vein. The subject of the changes produced on the portal

[1] Annalen der Chemie, u. s. w., Bd. xlviii., Heidelb., 1843; cited by Mr. T. Wharton Jones, in Brit. and For. Med. Rev., July, 1844, p. 259.

[2] Essai d'Hématologie Pathologique, p. 27, Paris, 1843.

[3] Rust, Magazin für die gesammt. Heilkund. Bde. 44, H. i., and Lond. Lancet, Aug. 10, 1839, p. 717.

[4] Animal Chemistry, Sydenham Society edition, p. 208, Lond., 1845.

blood, more especially as regards the quantity of red corpuscles, will be referred to when considering the functions of the SPLEEN.

The character and quantity of the different constituents of the blood, as well as its coagulation, vary greatly in disease; and the investigation is one of the most important in the domain of pathology. It is one that has attracted the attention of modern pathologists, and especially of MM. Andral and Gavarret, and of Simon, and MM. Becquerel and Rodier, who have endeavoured to detect the changes that occur in disease in the amount of the organic elements of the fluid. These the author has referred to in their appropriate places in another work.[1] The usual proportions of each element, in 1000 parts of healthy blood, according to M. Lecanu, adopted by MM. Andral and Gavarret, are as follows:—

Fibrin,	3
Red corpuscles,	127
Solid matter of serum,	80
Water,	790

The average of analyses of the blood of nine healthy individuals—four females and five males, by Dr. Ch. Frick, of Baltimore,[2] corresponds nearly with the above.

According to Simon,[3] the proportions are somewhat different,—a difference resulting in a great measure from a different method of analysis. The mean of his observations gave—

Water,	795·278
Solid residue,	204·022
Fibrin,	2·104
Fat,	2·346
Albumen,	76·600
Globulin,	103 022
Hematin,	6·209
Extractive matter and salts,	12 012[4]

The following table exhibits the mean composition of the blood, in eleven cases, as observed by MM. Becquerel and Rodier.[5]

Density of the defibrinated blood,	1060·2
" of the serum,	1028
Water,	779
Corpuscles,	141.1
Albumen,	69·4
Fibrin,	2·2
Extractive matters and free salts,	6·8
Fatty matters,	1·6
Serolin,	0·02
Fatty phosphuretted matter,	0·488
Cholesterin,	0·088
Soapy matter,	1·004

[1] Practice of Medicine, 3d edit., Philad., 1848.

[2] American Journal of the Medical Sciences, Jan., 1848, p. 27.

[3] Animal Chemistry, p. 245.

[4] It is proper to remark, with Simon, that the sum of the hematin and globulin, in his analysis, can never represent the absolute quantity of blood corpuscles. In his method the nuclei and capsules of the blood corpuscles are estimated as albumen; in that of Berzelius as fibrin; and in that of MM. Andral and Gavarret, as appertaining to the corpuscles.

[5] Gazette Médicale de Paris, Nos. 47, 48, 49, 50, and 51, for 1844.

One thousand parts of calcined blood contained—

Chloride of sodium,	3·1
Soluble salts,	2·5
Phosphates,	0·334
Iron,	0·565

From these numbers they draw the following deductions. *First.* The limits within which the composition of healthy blood varies are restricted, and probably dependent on constitution, age, and diet. *Secondly.* The number for the corpuscles exceeds 127, which has been regarded as expressing the healthy mean. *Thirdly.* The number for the fibrin, 2·2, is below that usually admitted as the mean of that element, 3.

The following tables have been constructed chiefly from the analyses of Denis, Lecanu, Simon, Nasse, Lehmann, Becquerel and Rodier, and Gavarret; and "are designed to combine, as far as possible, the advantage of accuracy in numbers with the convenience of presenting at one view a list of all the constituents of the blood."[1]

Average proportions of the chief constituents in 1000 parts:—

Water,	784
Red corpuscles,	131
Albumen of serum,	70
Saline matters,	6·03
Extractive, fatty and other matters,	6·77
Fibrin,	2·2
	1000·

Average proportion of all the constituents of the blood in 1000 parts:—

Water,		784
Albumen,		70
Fibrin,		2·2
Red corpuscles,		
globulin,		123·5
hematin,		7·5
Fatty matters:		
Cholesterin,	0·08	1·3
Cerebrin,	0·40	
Serolin,	0·02	
Oleic and margaric acids,		
Volatile and odorous fatty acid,		
Fat containing phosphorus,		
Inorganic salts:		
Chloride of sodium,		3 6
Chloride of potassium,		0·36
Tribasic phosphate of soda,		0·2
Carbonate of soda,		0·84
Sulphate of soda,		0·28
Phosphates of lime and magnesia,		0·25
Oxide and phosphate of iron,		0·5
Extractive matter, with salivary matter, urea, biliary colouring matter, gases and accidental substances,		5·47
		1000·

The mode in which the ratio of the various elements of the blood is estimated is detailed by MM. Andral and Gavarret, Simon, and Bec-

[1] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 54, Philad., 1849.

querel and Rodier, in the works referred to. A simpler method has, however, been given by M. Figuier,[1] founded on the fact made known by Berzelius, that after the addition of a solution of a neutral salt to defibrinated blood, the corpuscles do not pass through bibulous paper. On the addition of two parts of a solution of sulphate of soda, of specific gravity 1·130, to one of blood, M. Figuier found, that the whole of the corpuscles remained on the surface of the filter. The following is his procedure. The fibrin is removed in the usual way by whipping; and dried, and weighed. The weight of the corpuscles is then ascertained, and that of the albumen by coagulating the filtered solution by means of heat. The proportion of water is determined by evaporating a small known weight of the blood. The advantage of this plan consists in the facility with which the most important constituents may be determined without any difficult manipulations.

The proportion of fibrin, according to MM. Andral and Gavarret, may vary perhaps within the limits of health, from $2\frac{1}{2}$ to $3\frac{1}{2}$ parts in a thousand. The amount of red corpuscles appears to be subject to greater variation within the limits of health than that of the fibrin. The maximum is about 140, but this is connected with a plethoric condition: the minimum about 110. Strength of constitution contributes most to raise the corpuscles towards the maximum; whilst debility, congenital or acquired, diminishes them towards the minimum proportion. The solid matter of the serum likewise varies, but there is a certain point of diminution in health below which they do not pass.[2]

The analyses of MM. Becquerel and Rodier exhibit a marked difference in the proportion of the constituents of the blood of the two sexes. So great is this, that in order to attain correct conclusions in regard to morbid blood, it is indispensable to contrast it with the male or female blood in health. The average differences between the two are seen in the following table:—

	Male.	Female.
Density of defibrinated blood,	1060·0	1057·5
Density of serum,	1028·0	1027·4
Water,	779·0	791·1
Fibrin,	2·2	2·2
Sum of fatty matters,	1·60	1·62
Serolin,	0·02	0·02
Phosphorized fat,	0·488	0·464
Cholesterin,	0·088	0·090
Saponified fat,	1·004	1·046
Albumen,	69·4	70·5
Blood corpuscles,	141·1	127·2
Extractive matters and salts,	6·8	7·4
Chloride of sodium,	3·1	3·9
Other soluble salts,	2·5	2·9
Earthy phosphates,	0·334	0·354
Iron,	0·566	0·541

The main difference, consequently, between male and female blood is in the amount of water and blood corpuscles.[3]

[1] Annales de Chimie et de Physique, ii. 503, cited in Ranking's Abstract, i. 299, Amer. edit., New York, 1845.

[2] Andral, Hématologie Pathologique, p. 29, Paris, 1843.

[3] For the differences of blood, according to constitution, temperament, &c., see Simon, Animal Chemistry, Sydenham Society edition, p. 2[illegible], Lond., 1845, or Amer. edit., Philad., 1846.

The following table by Henle,[1] gives the results of the analyses of different observers as regards the proportion of the organic constituents of human blood, and the corresponding specific gravities of blood and serum.

	S. G. of Blood.	S. G. of Serum.	Water.	Blood Corpuscles.	Residue of Serum.	Fibrin.	Observer.	Remarks.
1	1062	1031	772	128	97	2	Popp.	
2	1061		781	121	86	10	do.	Many colourless corpuscles.
3	1057		773	142	82	3		Few do.
4	1055	1028	799	130	75	3	Becquerel and Rodier.	
5	1055	1027	793	126	78	2	do.	
6	1053		771	146	78	4	Popp.	
7	1053		781	140	76	2	do.	
8	1051		802	117	76	5	do.	
9	1050		790	114	90	5	do.	Many do.
10	1049		803	120	71	5	do.	do.
11	1049		806	92	96	5	do.	do.
12	1048		791	128	76	2	do.	
13	1048		814	104	76	5	do.	Few do.
14	1048		806	124	66	4	do.	
15	1048		801	107	86	5	do.	Many do.
16	1048		811	95	86	8	do.	A moderate number of do.
17	1047		811	118	65	6	do.	
18	1047		794	121	81	4	do.	
19	1046		790	129	78	2	do.	
20	1046	1023	831	105	54	2	Becquerel and Rodier.	
21	1045	1024		78		3	do.	
22	1044		827	91	71	11	Popp.	
23	1044		801	100	86	12	do.	
24	1044		790	115	83	11	do.	A strong buffy coat.
25	1043		826	93	72	9	do.	Few colourless corpuscles.
26	1043		812	112	66	10	do.	A moderate buffy coat.
27	1042		812	105	77	6	do.	Few colourless corpuscles.
28	1042		821	91	84	4	do.	
29	1042		828	95	74	3	do.	Many colourless corpuscles.
30	1042	1022		92	-	2	Becquerel and Rodier.	
31	1041		816	77	94	13	Popp.	Strong buffy coat.
32	1041		817	99	76	8	do.	
33	1040		831	92	68	9	do.	
34	1040		827	92	76	4	do.	
35	1039		855	68	72	6	do.	Few colourless corpuscles.
36	1039		845	96	80	5	do.	
37		1030	792	126	81	2	do.	
38		1026	788	124	82	6	Heller.	
39		1025	773	146	77	4	do.	
40		1025	834	78	83	5	do.	
41		1024	820	87	85	8	do.	
42		1023	782	147	65	6	do.	
43		1011			58		Popp.	Serum rich in fat.

[1] Handbuch der Rationellen Pathologie, 2er Band. s. 18, Braunschweig, 1847.

There is considerable difference, however, amongst observers in regard to the ratio of the different organic constituents of healthy blood, and this is dependent upon the different modes of evaluation adopted by them. It is advisable, therefore, in observations made on diseased blood, to follow the method employed by some one of them; and that of MM. Andral and Gavarret is generally chosen.

To exhibit this difference the following table drawn up by Henle[1] may be introduced:—

<table>
<tr><th>1000 parts of healthy venous blood contain</th><th>Corpuscles.</th><th>Water.</th><th>Fibrin.</th><th>Albumen.</th><th>Extractive matters.</th><th>Salts.</th></tr>
<tr><td>According to Le Canu,</td><td>127</td><td>790</td><td>3</td><td colspan="2">72</td><td>8</td></tr>
<tr><td>" Becquerel and Rodier,</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>of men,</td><td>141.1</td><td>779</td><td>2·2</td><td>69·4</td><td colspan="2">8·4</td></tr>
<tr><td>of women,</td><td>127·2</td><td>791·1</td><td>2·2</td><td>70·5</td><td colspan="2">9</td></tr>
<tr><td>" Popp,</td><td>120</td><td>790</td><td>2·5</td><td colspan="3">88</td></tr>
<tr><td>" Zimmerman,</td><td>127</td><td></td><td>3</td><td colspan="3">80</td></tr>
<tr><td>" Simon,</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>of men,</td><td>112·2</td><td>791·9</td><td>2·0</td><td>75·6</td><td colspan="2">16·6</td></tr>
<tr><td>of women,</td><td>106·0</td><td>798·6</td><td>2·2</td><td>77·6</td><td colspan="2">12·6</td></tr>
<tr><td>" Christison,</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>of men,</td><td>153·5</td><td>756·2</td><td>5·2</td><td colspan="3">85·3</td></tr>
<tr><td>of women,</td><td>120·7</td><td>795·2</td><td>2·5</td><td colspan="3">81·6</td></tr>
<tr><td>" Hittorf,</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>of women,</td><td>126·4</td><td>793·0</td><td>1·4</td><td>67·4</td><td colspan="2">11·5</td></tr>
</table>

A very recent analysis of healthy human blood by Scherer[2] gives the following proportion of the various constituents:—

	I.	II.	III.
Water, - - - -	783·18	769·64	775·7
Fixed parts, - - - -	216·82	230·36	224·3
Fibrin, - - - -	2·30	2·03	2·63
Albumen, - - - -	63·34	68·45	70·08
Blood corpuscles, - - -	139·92	146·22	138·71
Extractive matters, - - -	5·16	5·34	3·84
Soluble salts, - - - -	8·85	8·86	9·04
Fat, - - - -	1·70		

It may be added, that a peculiar entozoon,—*polystoma venarum, hexathyridium venarum*,—has been found in human venous blood, especially in that of persons affected with hæmoptysis; Treutler found one in the tibial vein of a young man, who had lacerated it whilst bathing. Vogel, however, suggests, that it may have been a planaria, which had entered the vein from without;[3] and Valentin several times observed minute entozoa—*anguillulæ intestinales*—in the circulating blood of frogs. MM. Gruby and Delafond[4] communicated to the *Académie Royale des Sciences* of Paris, the discovery of filariæ in the circulating fluid of a living dog.

[1] Op. cit., s. 73.

[2] Jahresbericht über die Fortschritte in der Biologie im Jahre, 1848, s. 65, Erlangen, 1849.

[3] The Pathological Anatomy of the Human Body, English translation by Day, p. 467, Lond., 1847.

[4] Philad. Med. Examiner, Jan. 13, 1844, from Comptes Rendus.

3. PHYSIOLOGY OF THE CIRCULATION.

The blood, contained in the circulatory apparatus, is in constant motion. The venous blood, brought from every part of the body, is emptied into the right auricle; from the right auricle it passes into the corresponding ventricle; and the latter projects it into the pulmonary artery, by which it is conveyed to the lungs, passing through the capillary system into the pulmonary veins; these convey it to the left auricle; from the left auricle it enters the corresponding ventricle; and the left ventricle sends it into the aorta, along which it passes to the different organs and tissues of the body, through the general intermediate or capillary system, which communicates with the veins; these return it to the part whence it set out. This entire circuit includes both the lesser and the greater circulation.

It was not until the commencement of the seventeenth century, that any precise ideas were entertained regarding the general circulation. In antiquity, the most erroneous notions prevailed; the arteries being generally looked upon as tubes for the conveyance of some aerial fluid to, and from, the heart; whilst the veins conducted the blood, whither or for what precise purpose was not understood. The names, given to the principal arterial vessel—*aorta*—and to the *arteries*, sufficiently show the functions originally ascribed to them,—both being derived from the Greek, αηρ, "air" and τηρειν, "to keep;" and this is farther confirmed by the fact, that the trachea or windpipe was originally termed an artery,—the αρτηρια τραχεια of the Greek,—*aspera arteria* of the Latin writers. In the time of Galen, however, the arteries were known to contain blood; and he seems to have had some notions of a circulation. He remarks, that the chyle, the product of digestion, is collected by the meseraic veins and carried to the liver, where it is converted into blood; the supra-hepatic veins then carry it to the pulmonary heart; whence a part proceeds to the lungs, and the remainder to the rest of the body, passing through the median septum of the auricles and ventricles. This limited knowledge of the circulation continued through the whole of the middle ages,—the functions of the veins being universally misapprehended; and the general notion being, that they also convey blood from the heart to the organs; from the centre to the circumference.

It was not until after the middle of the sixteenth century, that the lesser circulation or that through the lungs was comprehended by Michael Servetus,—who fell a victim to the persecution and intolerance of Calvin,—and of Andrew Cæsalpinus and Realdus Columbus. It has been imagined, that they possessed some notion of the greater circulation. Howsoever this may have been, all nations unite in awarding to Harvey the merit, if not of entire originality of at least having first clearly described it. The honour of the discovery is, therefore, his; and by it his name has been rendered immortal,—for its importance to the knowledge of the physiology and pathology of the animal fabric is overwhelming. How vague and inaccurate must have been the notions of the early pathologists regarding the doctrine of acute diseases, in which the circulation is always largely affected,—dis-

eases, which, according to the estimate of some writers, constitute two-thirds of the morbid states to which mankind are liable!

It was in the year 1619, that Harvey attained a full knowledge of the circulation; but his discovery was not promulgated until the year 1628, in a tract, to which the merit of clearness, perspicuity, and demonstration has been awarded by all.[1] Yet so strong is the force of prejudice, and so difficult is it to discard preconceived notions, that according to Hume,[2] it was remarked, that no physician in Europe, who had reached forty years of age, ever, to the end of his existence, adopted Harvey's doctrine of the circulation; and Harvey's practice in London diminished extremely for a time from the reproach drawn upon him by that great and signal discovery.

Of the truth of the course of the blood, as discovered by Harvey, we have numerous and incontestable evidences, which it is almost a work of supererogation to adduce. Of these the following are some of the most striking. *First.* If we open the chest of a living animal, we find the heart alternately dilating and contracting so as manifestly to receive and expel the blood in reciprocal succession. *Secondly.* The valves of the heart, and of the great arteries that arise from the ventricles, are so arranged as to allow the blood to flow in one direction, and not in another; and the same may be said of the veins, which are directed towards the heart. The tricuspid valve permits the blood to flow only from the right auricle into the corresponding ventricle; the sigmoid valves admit it to enter the pulmonary artery, but not to return; and, as there is, in the adult, no immediate communication between the right and left sides of the heart, the blood must pass along the pulmonary artery and the pulmonary veins to the left auricle. The mitral valve, again, is so situate, that the blood can only pass in one direction from auricle to ventricle; and, at the mouth of the aorta, the same valvular arrangement exists as in the pulmonary artery, which permits the blood to proceed along the artery, but prevents its reflux. *Thirdly.* If an artery and vein be wounded, the blood will be observed to flow from the part of the vessel nearest the heart in the case of the artery; from the other extremity in that of a vein. The ordinary operation of bloodletting at the flexure of the arm affords an elucidation of this. The bandage is applied above the elbow, for the purpose of compressing the superficial veins, but not so tightly as to compress the deep-seated artery also. The blood passes along the artery to the extremity of the fingers, and returns by the veins; but its progress back to the heart by the subcutaneous veins being prevented by the ligature, they become turgid; and, if a puncture be made, it flows freely. If, however, the ligature be applied so forcibly as to compress the main artery, the blood no longer flows to the extremity of the fingers; there is none, consequently, to be returned by the veins; they do not rise properly; and if a puncture be made no blood flows. This is not an unfrequent cause of the failure of an inexperienced phlebotomist. If the bandage, under such circumstances, be slackened, the blood resumes

[1] Exercitat. Anatom. de Motu Cordis et Sanguinis, Francof., 1628, Glasguæ, 1751.
[2] History of England, vol. vii. chap. lxii. p. 347, London, 1782.

its course along the artery, and a copious stream issues from the orifice, which did not previously transmit a drop. This operation, then, exhibits the fact of the flow of blood along the arteries from the heart, and of its return by the veins. From what has been said, too, it will be obvious, that if a ligature be applied to both vessels, the artery will become turgid above the ligature, the vein below it. *Fourthly.* The microscopical experiments of Leeuenhoek, Malpighi, Spallanzani, and others have exhibited to the eye the passage of the blood in successive waves by the arteries towards the veins, and its return by the latter. *Lastly.* The fact is farther demonstrated by the effect of transfusion of blood, and of the injection of substances into the vessels; both of which operations will be alluded to in another place.

In tracing the physiological action of the different parts of the circulatory apparatus, we shall follow the order observed in the anatomical sketch; and describe, in succession, the circulation in the heart, arteries, capillary vessels, and veins; on all of which points there has been interesting diversity of opinion, and much room for ingenious speculation, and farther improvement.

a. *Circulation in the Heart.*

It has been already observed, that when the heart of a living animal is exposed, it is remarked to undergo alternate contraction and dilatation. The mode, in which the circulation through the organ is accomplished is generally considered to be as follows: The blood is received into the two auricles at the same time, and is transmitted into the two great arteries synchronously. In order that the heart shall receive blood, it is necessary that the auricle should be dilated. This movement is partly effected by virtue of the elasticity which it possesses in its structure. Let us suppose it to be once filled; the stimulus of the blood excites it to contraction, and the blood is sent into the corresponding ventricle. As soon, however, as it has emptied itself, the stimulus is withdrawn; and, by virtue of its elasticity the muscular structure returns to the state in which it was prior to its contraction. An approach to a vacuum is thus formed in the cavity, and the blood from the veins is solicited towards it, until it is again filled, and its contraction renewed. When the right auricle contracts there are four channels by which the blood might be presumed to pass from it,—the two terminations of the venæ cavæ; the coronary vein, and the auriculo-ventricular opening. The constant flow of blood from every part of the body prevents it from readily returning by the venæ cavæ, whilst the small quantity, which, under other circumstances, might have entered the coronary vein, is prevented by its valve. To the flow of the blood through the aperture into the ventricle, which is in a state of dilatation, there is no obstacle, and accordingly it takes this course, raising the tricuspid valves.

It may be remarked, that physiologists are not entirely of accord regarding the reflux of blood into the venæ cavæ. Some think, that this always occurs to a slight extent; others, never in the healthy state. Its existence is unequivocal, where an obstacle occurs to the due discharge of the blood into the ventricle. For example, if there is any

impediment to the flow of blood along the pulmonary artery, either owing to mechanical obstruction or to diminished force of the ventricle, the reflux is manifested by a kind of pulsation in the veins, which Haller has called *venous pulse.*

The blood having attained the right ventricle by the effort exerted by the contraction of the auricle, and by the aspiration exerted by the dilatation of the cavity through the agency of its elastic structure, the ventricle contracts. Into it there are but two apertures, the auriculo-ventricular, and the mouth of the pulmonary artery. By the former, much of the blood cannot escape, owing to the tricuspid valve, which acts like the sail of a ship,—the blood distending it as the wind does a sail, and the chordæ tendineæ retaining it in position, so that the greater part of the blood is precluded from reflowing into the auricle. This auriculo-ventricular valve is not, however, as perfect as that of the left heart. The observations of Mr. T. W. King[1] show, that whilst the structure of the mitral valve is adapted to close completely all communication between the left auricle and left ventricle during the contraction of the latter, that of the tricuspid valve is designedly calculated to permit, when closed, the flow of a certain quantity of blood into the auricle. The comparatively imperfect valvular function of the tricuspid was shown by various experiments on recent hearts, in which it was found, that fluids, injected through the aorta into the left ventricle, were perfectly retained in that cavity by the closing of the mitral valve; but when the right ventricle was similarly injected through the pulmonary artery, the tricuspid valves generally allowed the escape of the fluid in streams more or less copious, in consequence of the incomplete apposition of their margins. This peculiarity of structure in the tricuspid, Mr. King regards as an express provision against the mischiefs, that might result from an excessive afflux of blood to the lungs,—thus acting as a safety valve, and being more especially advantageous in incipient morbid enlargements of the right ventricle. The only other way the blood can escape from the right ventricle is by the pulmonary artery, the sigmoid valves of which it raises. These had been closed like flood-gates, during the dilatation of the ventricle; but they are readily pushed outwards, by the columns transmitted from the ventricle.

Such is the circulation through one heart,—the *pulmonic.* The same explanation is applicable to the other,—the *systemic;* and hence it is, that the structure, as well as the functions of the heart, is so much better comprehended, by conceiving it to be constituted of two essentially similar organs.

The above description is that which is usually given of the circulation through the heart. There is great reason, however, for the belief, that too much importance has been assigned to the distinct contraction of the auricles. If we examine their anatomical arrangement we discover, that there are no valves at the mouths of the great veins which open into them, and that although in the proper auricle or dog's ear portion muscular fibres and columns exist,—somewhat analogous to those of the columnæ carneæ of the ventricles, and probably destined for

[1] Guy's Hospital Reports, No. iv. for April, 1837.

similar uses,—the parietes of the main portions of the auricles,—those that constitute the venous sinuses are but little adapted for energetic contraction. In experiments on living animals observation shows, that the rhythmic acts of dilatation and contraction are more signally exhibited by the ventricle, and, moreover, in some monsters the auricles are wanting, and in birds very small. M. d'Espine considers the auricles, in receiving or transmitting blood, to have only a vermicular motion, not one of contraction; and in a case of monstrosity, described by Dr. T. Robinson,[1] of Petersburg, Virginia, no distinct systole and diastole of the auricles could be detected. Besides, if we admit both an active power of dilatation and contraction in the ventricles, any similar action of the auricles would seem to be superfluous. In the state of active dilatation of the ventricles, the blood is drawn into their cavities; and as soon as they enter into contraction, the auriculo-ventricular valves prevent the farther entrance into them of blood arriving in the auricles by the large veins; and give occasion to the distension of the auricles; in this way, the dilatation of the auricles, synchronous with the contraction of the ventricles, is accounted for. As soon as the ventricle has emptied itself of its blood, it dilates actively; the blood then passes suddenly from the auricle into its cavity through the auriculo-ventricular opening.

From careful experiments instituted by Drs. Pennock and Moore,[2] they drew the following conclusions, which have been confirmed by the observations of others, and merit universal assent. The ventricles contract and the auricles dilate at the same time, occupying about one-half of the whole time required for contraction, diastole, and repose. Immediately at the termination of the systole of the ventricle, its diastole occurs, occupying about one-fourth of the whole time, synchronously with which the auricle diminishes, by emptying a portion of its blood into the ventricle, but without muscular contraction. The remaining fourth is devoted to the repose of the ventricles, near the termination of which the auricle contracts actively, with a short, quick motion, thus distending the ventricles with an additional quantity of blood: this motion is propagated immediately to the ventricles, and their systole follows so rapidly as to make the contraction of auricle and ventricle almost continuous. From the termination of their diastole to the commencement of the systole, the ventricles are in a state of perfect repose; their cavities remaining full but not distended; whilst those of the auricles are partially so, during the whole time. It appears probable, that the great use of the auricles—in which we include the sinuses—is to act as true gulfs for the reception of the blood proceeding from every part of the body;—and that little effect is produced on the circulation by their varying condition.[3]

The state of the heart in which the ventricles are dilated is termed *Diastole;* that, in which they are contracted, *Systole.*

[1] American Journal of the Medical Sciences, No. xxii. for February, 1833.

[2] Medical Examiner, Nov. 2, 1839, and American Medical Intelligencer, Dec. 16, 1839, p. 277.

[3] See, on this subject, Elliotson's Human Physiology, p. 174, Lond., 1840.

Since the valuable improvement, introduced by M. Laënnec in the discrimination of diseases of the chest by audible evidences, it has been discovered, that the heart is not in a state of incessant activity, but has, like other muscles, its intervals of repose. If we apply the ear or the stethoscope to the præcordial region, we hear, first, a dull, lengthened sound, which, according to Laënnec,[1] is synchronous with the arterial pulse, and is produced by the contraction of the ventricles. This is instantly succeeded by a sharp, quick sound, like that of the valve of a bellows or the lapping of a dog. To convey a notion of these sounds, Dr. C. J. B. Williams employs the word *lubb-dup* or *lubb-tub;*—the first word of the compound expressing the protracted first sound—and the latter the short second sound. The latter sound corresponds to the interval between two pulsations, and, according to Laënnec, is owing to the contraction of the auricles. The space of time, that elapses between this and the sound of the contraction of the ventricles, is the period of repose. The relative duration of these periods is as follows:—one-half, or somewhat less, for the contraction of the ventricles; a quarter, or somewhat more, for the contraction of the auricles; and the remaining quarter for the period of total cessation from labour. So that in the twenty-four hours the ventricles work twelve hours, and rest twelve; and the auricles work six, and rest eighteen.

Such is the view of Laënnec; but it is manifestly erroneous. Ocular observation on living animals, as Dr. Alison[2] has remarked, shows that the emptying of the auricle precedes that of the ventricle, and that the interval of rest is between the contraction of the ventricle and the next contraction or emptying of the auricle: between the contraction of the auricle and that of the ventricle, there is no appreciable interval. Puchelt[3] thinks it most probable, that the first sound is caused by the impulse of the blood against the walls of the ventricle during the contraction of the auricles, and the second by the impulse of the blood against the commencement of the arteries during the contraction of the ventricles. In regard to the first sound, M. Beau[4]—and M. Valleix[5] accords with him—agrees pretty nearly with Puchelt. He ascribes it to the wave of blood striking against the parietes of the ventricles during the ventricular diastole. The second sound he ascribes, however, to the shock of the column of blood arriving by the veins against the parietes of the auricles. M. d'Espine thinks, that the first sound is produced by the contraction of the ventricles, and that the second is owing to their dilatation.[6]

The following table by Messrs. Kirkes and Paget[7] exhibits the different actions of the heart, and their coincidence with the sounds and impulse of the organ. It presumes, that the period from the commencement of one pulsation to that of another—or that occupied by a

[1] A Treatise on the Diseases of the Chest, translated by Dr. Forbes, 4th edit., Lond., 1834.
[2] Outlines of Physiology, Lond., 1831.
[3] System der Medicin., th. i. Auflage 2te, s. 149, Heidelb., 1835.
[4] Archiv. Général de Méd., Dec., 1835, Janvier, 1839, Juillet, 1841.
[5] Guide du Médecin Praticien, tom. iii. p. 34, Paris, 1843.
[6] Revue Médicale, Oct., 1831. [7] Manual of Physiology, Amer. edit., p. 75, Lond., 1849.

complete set of the heart's actions—is divided into eight parts; and if the case of a person, whose pulse beats sixty times in a minute, be assumed, each of these parts will represent the eighth part of a second.

	EIGHTHS OF A SECOND.
Last part of the pause, -	1. Auricles contracting: Ventricles distended.
First sound and impulse, -	4. Ventricles contracting: Auricles dilating.
Second sound, - - -	2. Ventricles dilating: Auricles dilating.
Pause, - - - -	1. Ventricles dilating: Auricles distended.

Our knowledge of the cause of the sounds of the heart is sufficiently imprecise; as is farther proved by the circumstance, that M. Magendie ascribed the first sound to the shock or impulsion of the apex of the heart during its diastole, and the second to the impulsion of the base of the heart during its systole; but the results of more recent experiments[1] have led him to infer, that the first sound is owing to the contraction of the ventricles, and the impulse of the apex of the heart against the ribs; and the second to a similar impulse of the anterior part of the heart, produced by their dilatation. M. Rouanet[2] ascribes the first or dull sound to the shock or impulse of the tricuspid and mitral valves against the auriculo-ventricular orifices; and the second or clear sound to the succussion of the blood in the distended aorta and pulmonary artery backwards against the semilunar valves, during the dilatation of the ventricles; and a similar opinion is entertained by Dr. Hope and by Messrs. Mayo[3] and Bouillaud.[4] In evidence that the first sound is due to the tension of the auriculo-ventricular valves, M. Valentin[5] states, that if a portion of a horse's intestine tied at one end be moderately filled with water, without any admixture of air, and have a syringe containing water adapted to the other end, the first sound of the heart will be exactly represented by forcing more water in. It may be distinctly heard with the stethoscope applied near the tied extremity of the intestine, at the instant the water from the syringe renders it tense. Mr. Carlisle[6] and Dr. Williams[7] refer the first sound, with Laënnec, to the systole of the ventricles, and the second to the obstacle presented by the semilunar valves to the return of the blood from the arteries into the heart,—and Messrs. Corrigan,[8] Pigéaux,[9] Stokes,[10] and Mackintosh,[11] think the first sound is owing to the systole of the venous sinuses, and the second to the systole of the ventricles—an opinion, which Burdach[12] thinks is best founded, but which, as we have seen, is manifestly erroneous.

1 Annales des Sciences Naturelles, 1834.
2 Ibid. No. xcvii.
3 Outlines of Human Pathology, p. 465, Lond., 1836.
4 Journal Hebdomad. No. ix., 1834.
5 Lehrbuch der Physiologie des Menschen, i. 427, Braunschweig, 1844.
6 Report of the Third Meeting of the British Association for the Advancement of Science; and Amer. Journal of Med. Sciences, p. 477, for Feb., 1835.
7 A Rational Exposition of the Physical Signs of Diseases of the Lungs and Pleura, Amer. edit., Philad., 1830.
8 Dublin Med. Trans., vol. i., New Series.
9 Bulletin des Sciences Médicales, par Férussac, xxv. 272.
10 Edinb. Med. and Surg. Journal, vol. xxxiv.
11 Principles of Pathology, &c., 2d Amer. edit., ii. 6, Philad., 1837.
12 Die Physiologie als Erfahrungswissenschaft, iv. 219, Leipz., 1832.

In a case of ectopia cordis, described by M. Cruveilhier,[1] a distinct vibratory thrill was perceived, by applying the finger to the origin of the pulmonary artery, which corresponded with the ventricular systole; but no such thrill could be felt when the finger was applied to any part of the base of the ventricles. He inferred, therefore, that the first sound cannot be dependent upon the action of the auriculo-ventricular valves. The greatest intensity of the first sound was, indeed, in the same situation as the greatest intensity of the second, that is, at the origin of the large arteries. Dr. Carpenter[2] thinks the results of these observations of Cruveilhier clearly establish, that the principal cause of the first sound exists at the entrances to the arterial trunks; and it does not seem to him, that any other reason can be assigned for it than the prolonged rush of blood through their orifices, and the throwing back of the semilunar valves, which, in suddenly flapping down again, produce the second sound. M. Cruveilhier states it, in his opinion, to be a uniform occurrence, that disease of the semilunar valves modifies both sounds;—a fact, which the author has long noticed. Without expressing an opinion as to the validity of M. Cruveilhier's conclusion regarding the two sounds of the heart, Dr. Forbes evidently regards it with favour, under the view long maintained by him, that although characteristically different, the two sounds have so great a similarity, and are so allied in time and place, that he could not readily bring his mind to believe, that they do not both depend upon one and the same cause slightly modified; or at least on the different play of the same parts.[3]

Drs. Pennock and Moore,[4] who agree in the main with Dr. Hope, found the first sound, the impulse, and the systole of the ventricles to be synchronous; and the second sound to be synchronous with the diastole of the ventricles. The first sound, they suggest, may be a combination of that caused by the contraction of the auricles, the flapping of the auriculo-ventricular valves, the rush of blood from the ventricles, and the sound of muscular contraction. In four of their experiments, when the heart was removed from the body, the ventricles cut open and emptied of their contents, and the auriculo-ventricular valves elevated, a sound resembling the first was still heard, which they attributed chiefly to muscular contraction. The second sound they referred exclusively to the closure of the semilunar valves by the refluent blood from the aorta and pulmonary artery. "This," they remark, "is proved by the greater intensity of this sound over the aorta than elsewhere, the blood having a strong tendency to return through the valvular opening; by the greater feebleness of the sound over the pulmonary artery, which is short, and soon distributes its blood through the lungs, thus producing but slight impulse upon the valves in the attempt to regurgitate; by the disappearance of the sound when the heart becomes congested and contracts feebly; and finally, on account of its entire extinction when the valve of the aorta was elevated."

The main results of the experiments of Drs. Pennock and Moore

[1] Gazette Méd. de Paris, 7 Août, 1841, p. 535; or Brit. and For. Med. Review, Oct., 1841, p. 535.
[2] Human Physiology, § 486, Lond., 1842.
[3] Translation of Laënnec, 4th edit.; and Brit. and For. Med. Review, loc. cit.
[4] Op. citat.

accord closely with what the author has entertained and taught on this subject; but the views of M. Cruveilhier are well worthy of attention. The whole matter is still open for further investigation. A case of thoracic ectopia has been published by M. Monod,[1] in which the maximum intensity of the first sound did not occur at the base of the ventricles, but at the middle of their fleshy walls; and M. Monod thinks, that it was caused by the shock of the walls of the ventricles against the internal fleshy columns at the moment of contraction. As to the second sound, he is of opinion, that it was owing to the return of the wave of blood against the semilunar valves.

More recently, the mechanism by which the valves of the heart are closed, and its sounds produced has been subjected to a fresh investigation by Baumgarten, and subsequently by Hamernjk,[2] and others. According to them, there is, during the systole of the auricles, very little regurgitation into the venous trunks, owing, in part, to an arrangement of circular muscular fibres surrounding their openings into the auricles, as well as to the other causes generally admitted. The auriculo-ventricular valves—they conceive—are closed by the counterpressure of the ventricular blood, such counterpressure being suddenly developed by the contraction of the auricles. The cavities of the auricles and ventricles, during the diastole of the heart, are distended by the continuous current from the veins; and at this period the valves are floating in the blood in the form of a funnel. The object of the auriculo-ventricular systole is to induce such a degree of tension in the contents of the ventricles, and of necessity in the blood surrounding the funnel-shaped arrangement of the valves, as to cause their rapid closure and prevent regurgitation. Such closure is not due to the contraction of the musculi papillares, but is much facilitated by the small specific gravity of the valves, which enables them to float on the surface of the blood. The mechanism, by which the valves of the arteries are closed, is similar to that of the auriculo-ventricular valves. Immediately on the contraction of the ventricles, the pressure of the blood, contained in the large arterial trunks, acting equally in all directions, produces the closure of the semilunar valves,—their complete closure occurring synchronously with the end of the ventricular systole. When the diastole of the ventricle commences, the arterial retraction begins, and the refluent blood from the large arteries falls on the valves already closed, and causes the second sound; but there is no regurgitation, as there necessarily would be—M. Hamernjk maintains—were the valve shut out by the returning wave of blood. The first sound, according to this view, is occasioned by the vibration of the tense auriculo-ventricular valves, caused by the blood forced against them in the systole of the ventricles, and the vibration of the chordæ tendineæ. In like manner, the second sound is produced by the

[1] Bullet. del. Académ. Royale de Méd., 7 Février, 1843; cited in Edinb. Med. and Surg. Journal, July, 1843.

[2] Edinburgh Monthly Journal for Jan., 1849, cited from Prager Vierteljahrschrift, 1847 and 1848; see, also, Schmidt's Jahrbucher, No. 1, s. 10, Jahrgang, 1848, and No. 5, s. 151 Jahrgang, 1849.

impulse of the blood on the semilunar valves already shut, and not by their closure, as usually supposed.

The following table, compiled in part by MM. Barth and Roger,[1]—to which additions have been made by the author—affords at a glance the discordant opinions entertained by observers in regard to this important topic of physiology,—an accurate knowledge of which is essential to the correct understanding of cardiac diseases.

	FIRST SOUND CAUSED BY	SECOND SOUND CAUSED BY
LAENNEC,	Ventricular contraction.	Auricular contraction.
TURNER,	Do.	Shock of the heart falling back upon the pericardium during the diastole.
CORRIGAN,	Shock of the blood against the ventricular parietes during the diastole.	Reciprocal shock of the internal surface of the opposite parietes of the ventricles during the systole.
D'ESPINE,	Ventricular contraction.	Ventricular dilatation.
PIGEAUX, 1832,	Shock of the blood against the ventricular parietes at the moment of the diastole.	Shock of the blood against the parietes of the aorta and pulmonary artery at the moment of the systole.
PIGEAUX, 1839,	Friction of the blood against the parietes of the ventricles, the orifices and parietes of the great vessels at the moment of the systole.	Friction of the blood against the parietes of the auricles, the auriculo-ventricular orifices, and the cavity of the ventricles at the moment of the diastole.
HOPE, 1831,	Molecular collision of the blood in the systole.	Molecular collision of the blood in the diastole.
HOPE, 1839,	Sound of tension of the valves, sound of muscular extension, rotatory sound in the systole.	Clacking of the semilunar valves in the diastole.
ROUANET,	Clacking of the auriculo-ventricular valves in the systole.	Do.
PIORRY,	Friction of the molecules of the blood against each other, and against the parietes of the ventricles, the orifices, and the valves, during the systole of the left ventricle.	Passage of the blood into the right cavities. Into what parts? At what moment?
CARLISLE,	Irruption of the blood into the arteries during the systole.	Clacking of the semilunar valves in the diastole.
MAGENDIE,	Shock of the apex of the heart against the thorax at the moment of the systole.	Shock of the anterior surface of the heart at the moment of the diastole.
BURDACH,	Irruption of the blood into the ventricles containing air (?) at the moment of the contraction of the auricles.	Projection of the blood into the arteries containing air (?) at the moment of the systole.
BOUILLAUD,	Sudden tension (*redressement*) and shock of the opposed surfaces of the auriculo-ventricular valves, and sudden depression of the semilunar valves during the systole.	Tension (*redressement*) of the semilunar valves, and shock of their opposed surfaces, and sudden depression of the auriculo-ventricular valves at the moment of the diastole.
GENDRIN,	Vibrations resulting from the collision of the blood in the systole.	Percussion of the blood against the parietes of the ventricles at the moment of the diastole.
CRUVEILHIER,	Sudden tension (*redressement*) of the semilunar valves by the systole.	Depression of these valves at the moment of the diastole.

[1] Traité Pratique d'Auscultation, &c., 2de édit., p. 359, Paris, 1844.

	FIRST SOUND CAUSED BY	SECOND SOUND CAUSED BY
SKODA,	*First ventricular sound.* Shock of the blood against the auriculo-ventricular valves; impulsion of the apex of the heart against the thorax.	*Second ventricular sound.* Shock of the columns of the blood against the parietes of the ventricles in the diastole.
	First arterial sound. Shock of the blood against the parietes of the aorta, and of the pulmonary artery in the systole.	*Second arterial sound.* Retrograde shock of the column of blood upon the semilunar valves.
BEAU,	Shock of the wave of blood against the parietes of the ventricles in the ventricular diastole.	Shock of the column of blood, arriving by the veins against the parietes of the auricles.
C. J. B. WILLIAMS,	Muscular contraction of the ventricles during the systole.	Return shock of the columns of blood against the semilunar valves during the diastole.
DUBLIN COMMITTEE,	Friction of the blood against the parietes of the ventricles, and muscular contraction during the systole.	Tension of the semilunar valves, and return shock of the columns of blood during the diastole.
LONDON COMMITTEE,	Sudden muscular tension of the ventricles in the systole, and shock of the heart against the thorax.	Sudden occlusion of the semilunar valves by the arterial columns of blood.
PENNOCK AND MOORE,	Muscular contraction of the ventricles and clacking of the auriculo-ventricular valves during the systole.	Occlusion of the semilunar valves by the return shock of the arterial columns of blood.
BARTH AND ROGER,	Contraction of the ventricles: shock at the inferior surface of the semilunar valves, and at the base of the aortic and pulmonary columns of blood; clacking of the auriculo-ventricular valves; and impulse of the heart against the chest.	Tension of the semilunar valves; and return shock of the blood on their concave surface.
BAUMGARTEN AND HAMERNJK.	The vibration of the tense auriculo-ventricular valves acted on by the blood sent against them during the systole of the ventricles, and the vibration of the chordæ tendineæ.	The impulse of the blood on the semilunar valves already shut, not by their closure.

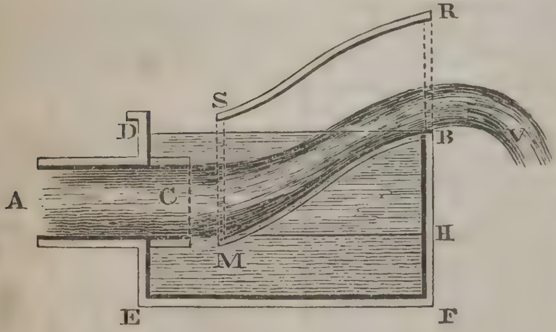
It has been a question with physiologists, whether the cavities of the heart completely empty themselves at each contraction. Sénac,[1] and Thomas Bartholine,[2] from their experiments, were long ago led to answer the question negatively. On the other hand, Haller[3] entertained an opposite opinion,—suggested, he remarks, by his experiments; but, perhaps, notwithstanding all his candour, connected, in some manner, with his doctrine of irritability, which could not easily admit the presence of an irritant in a cavity that had ceased to contract. It has been remarked by M. Magendie,[4] that if we notice the heart of a living animal, whilst it is in a state of action, it is obvious, that the extent of the contractions cannot have the effect of completely emptying the ventricles; but it must, at the same time, be admitted, that such experiments are inconclusive, inasmuch as they exhibit to us the action of the organ under powerfully deranging influences, and such as could be

[1] Traité de la Structure du Cœur, &c., 2de édit., Paris, 1774.
[2] Dissertat. de Corde, Hafn., 1648.
[3] Element. Physiol., lib. iv. sect. 4, § 7, Lausann., 1757.
[4] Précis, &c., tom. ii.

readily conceived to modify materially the extent of the contractions. The same may be said of a case of monstrous fœtus observed by Dr. Thomas R. Mitchell.[1] After each contraction of the ventricle he was able to make blood pass into the aorta. If the heart of a frog be examined by cutting out the lower portion of the sternum, owing to the transparency of the parietes of the heart, it can be observed that the ventricle completely empties itself at each contraction; but Dr. Mitchell is decidedly of opinion, that the frog is not a fit subject from which to draw a conclusion, and agrees with Mr. Carlisle, that the cavities empty themselves more completely in the lower order of animals than in the higher. These observations, however, are insufficient to prove, that whilst an animal is in a normal condition, the auricles and ventricles are not emptied of their contents by their contraction.

The objection urged against the opposite view, that there would always be stagnant blood in the cavities of the heart, is not valid. The experiments of Venturi[2] have shown, that even in an ordinary hydraulic apparatus, the motion of a stream passing through a vessel of water is communicated to the fluid at rest in the vessel, so that an incessant change is produced. Let us suppose a stream of water to enter the vessel D E F B, Fig. 296, which is full of fluid, by the pipe A C, and that opposite to this pipe is the tube S M B R. The stream will pass up this tube higher than the vessel, and discharge itself at B V. At the same time, the fluid in the vessel will be observed to be in motion, and, in a few seconds, the level in the vessel will fall from D B to H M.

Fig. 296.



During the systole of the heart, the organ is suddenly carried forward; and although it appears to be rendered shorter, its point or apex is generally considered to strike the left side of the chest opposite the interval between the fifth and seventh true ribs; producing what is called the "beating of the heart." The cause of this phenomenon was, at one period, a topic of warm controversy. Borelli,[3] Winslow, and others, affirmed, that it was owing to the organ being elongated during contraction; but to this it was replied by Bassuel,[4] that if such elongation took place, the tricuspid and mitral valves, kept down by the columnæ carneæ, could not possibly close the openings between the correspond-

[1] Dublin Journal of Medical Science, Nov., 1844, p. 275.

[2] Sur la Communication Latérale du Mouvement dans les Fluides, Paris, 1798; and Sir C. Bell, in Animal Mechanics, p. 35, Library of Useful Knowledge, Lond., 1829.

[3] De Motu Animalium, Lugd. Bat., 1710.

[4] Magendie, Précis, &c., ii. 395.

ing auricles and ventricles. Experiments by Drs. Pennock and Moore[1] exhibited to them, that the expulsion of the blood from the ventricles was effected by an approximation of the sides of the heart, and not by a contraction of the apex towards the base; and that, during the systole, the heart performs a spiral movement, and becomes elongated. Sénac[2] ascribed the beating of the heart to three causes, and his views have been adopted by most physiologists:—1, to the dilatation of the auricles, which occurs during the contraction of the ventricles; 2, to the dilatation of the aorta and pulmonary artery by the introduction of blood sent into them by the ventricles; and 3, to the straightening of the arch of the aorta, owing to the blood being forced against it by the contraction of the left ventricle. Dr. William Hunter[3] considered the last cause quite sufficient to explain the phenomenon, and many physiologists have assented to his view.

Sir David Barry[4] instituted some experiments upon this subject. He opened the thorax of a living animal, and by passing his hand into the cavity, endeavoured to ascertain the actual condition of the heart and great vessels, as to distension and relative position. He performed seven experiments of this kind, from which he concluded, that the vena cava is considerably increased in size during inspiration, which he ascribes, as will be better understood hereafter, to the partial vacuum formed in the chest. He supposes that the force exerted by the venous blood on entering the heart, in consequence of the expansion of the chest and the great vessels behind the heart, pushes the organ forwards, and thus causes it to strike against the ribs. Dr. Corrigan thinks, that the apex of the heart has nothing to do with the impulse. He is of opinion that the heart acts like any other muscle,—that as soon as the ventricles contract, it is shortened from below upwards, and by this shortening becomes thickened in the middle, in a similar manner to the thickening of the belly of the biceps muscle, which, when it contracts, gives rise to an evident impulse, plainly perceptible to the hand applied to it; and that in like manner the heart's impulse is owing to the body of the ventricles, and not to the apex, striking against the ribs. Dr. Corrigan's view is considered by Dr. T. R. Mitchell,[5] to be confirmed by the phenomena observed by him on a fœtus born with the left side of the thorax wanting; and in which the action of the heart could be closely observed. Drs. Pennock and Moore,[6] however, in their experiments, found that the impulse was synchronous with and caused by the contraction of the ventricles, and, when felt externally, arose from the striking of the apex against the thorax. To show, however, that this apparently simple matter cannot be considered settled, Professor Müller[7] thinks that great uncertainty rests as to whether the impulse be produced during the contraction or the dilatation of the ventricles.

In proof, however, that the impulse of the heart is dependent on the contraction of the muscular fibres of the ventricles, the experiments of

[1] Med. Examiner, Nov. 2, 1839. [2] Traité de la Structure du Cœur, &c., Paris, 1749.
[3] John Hunter, Treatise on the Blood, p. 146, Lond., 1794.
[4] Exper. Researches on the Influence of Atmospheric Pressure upon the Circulation, Lond., 1826.
[5] Dublin Journal of Med. Science, Nov., 1844, p. 271. [6] Op. citat.
[7] Handbuch, u. s. w., Baly's translation, p. 175, Lond., 1838.

Valentin[1] may be cited. He cut off the apex of the heart in several cases, so that the resistance of the blood and the great vessels, and the supposed consequent recoil, were prevented; yet the tilting movement was observed as much as when the heart was entire. It has even been supposed that the impulse is produced by the blood sent into the ventricles by the contraction of the auricles, but it must be borne in mind, in the inquiry, that there is no appreciable interval between the contraction of the auricles, and that of the ventricles.

The systole of the heart is admitted by all to be active. Some are disposed to think the diastole passive,—that is, the effect of relaxation of the fibres or the cessation of contraction. Pechlin, Perrault, Hamberger, d'Espine, Alison, and numerous others, have supported an opposite view;—affirming that direct experiment on living animals shows, that positive effort is exerted at the time of the dilatation of the cavities;—a view confirmed by the case of monstrosity related by Dr. Robinson.[2] His opinion is, that the force of the diastole was in that case equal to, if not greater than, that of the systole. In the case, too, observed by M. Cruveilhier, the diastole had the rapidity and energy of a very active movement, overcoming pressure made upon the heart, so that the hand closed upon it when it was contracted was opened with violence. It has been suggested, that if the course of all the fibres composing the muscular parietes of the organ were better known, this apparent anomaly might, perhaps, be as easily explained as in the ordinary case of antagonist muscles. It is probable, however, that the active force exerted in the dilatation of these cavities is that of elasticity; and when the contraction of the muscular fibres has ceased, this is aroused to action, and promptly restores the organ to its previously dilated condition. According to this view, the natural state would be that of dilatation. We shall see, hereafter, that elasticity is probably one of the agents of the circulation of the blood along the vessels.

The cause of the heart's action has been a deeply interesting question to the physiologist, and, in the obscurity of the subject, has given rise to many and warm controversies. From the first moment of fœtal existence, at which the organ becomes perceptible, till the cessation of vitality it continues to move. By many of the ancients this was supposed to be owing to an inherent *pulsific virtue*,[3] which enabled it to contract and dilate alternately,—a mode of expression, which, in the infancy of physical science, was frequently employed to cover ignorance, and has been properly and severely castigated by Molière:—

> "Mihi a docto doctore
> Domandatur causam et rationem quare
> Opium facit dormire.
> A quoi respondeo;
> *Quia est in eo*
> *Virtus dormitiva,*
> Cujus est natura
> Sensus assoupire."
>
> LE MALADE IMAGINAIRE, Intermède iii.

[1] Lehrbuch der Physiologie des Menschens, i. 427.
[2] Amer. Journal of the Medical Sciences, No. xxii., Feb., 1833.
[3] Haller, Elementa Physiologiæ, lib. iv. sect. v. § 1.

It was in ridicule of the same failing that Swift represented the action of a smokejack to be depending on a meat-roasting power.[1] Descartes[2] imagined that an explosion took place in the ventricles as sudden as that of gunpowder. With equal nescience, the phenomenon was ascribed by Van Helmont[3] to his imaginary archæus; and by Stahl,[4] and the rest of the animists, to the *anima*, soul or intelligent principle, which he supposed to preside over all the mental and corporeal phenomena. Stahl was one of the first that attempted any rational explanation of the heart's action. Its muscular tissue; the similarity of its contractions to those of ordinary muscles, with the exception of their not being voluntary; the fact of its action being modified by the passions, &c., led him to liken its movements to those of muscles. He admitted, that, generally, we possess neither perception of, nor power over, its motions; but he affirmed, that habit alone had rendered them involuntary; in the same manner as certain muscular twitchings or *tics*, which are at first voluntary, may become irresistible by habit. A strong confirmation of this opinion was drawn from the celebrated case of the honourable Colonel Townshend, (called by M. Adelon[5] and other French writers, Captain Towson,) who was able, (not all his life, as Adelon asserts, but a short time before his death,) to suspend the movements of his heart at pleasure. This case is of so singular a character, in a physiological as well as pathological point of view, that we shall give it in the words of Dr. George Cheyne,[6] one of the physicians who attended him, and whose character for veracity is beyond suspicion. "Colonel Townshend, a gentleman of excellent natural parts, and of great honour and integrity, had, for many years, been afflicted with constant vomitings, which had made his life painful and miserable. During the whole time of his illness he had observed the strictest regimen, living on the softest vegetables and lightest animal food; drinking asses' milk daily, even in the camp; and for common drink Bristol water, which, the summer before his death, he had drunk on the spot. But his illness increasing, and his strength decaying, he came from Bristol to Bath in a litter, in autumn, and lay at the Bell Inn. Dr. Baynard, who is since dead, and I were called to him, and attended twice a day for about the space of a week: but, his vomitings continuing still incessant, and obstinate against all remedies, we despaired of his recovery. While he was in this condition, he sent for us early one morning; we waited on him with Mr. Skrine, his apothecary (since dead also); we found his senses clear, and his mind calm; his nurse and several servants were about him. He had made his will and settled his affairs. He told us he had sent for us to give him some account of an odd sensation he had for some time observed and felt in himself, which was that, composing himself, he could *die* or *expire* when he pleased, and yet by an effort, or somehow, he could come to life again; which it seems he had sometimes tried before he had sent for us. We heard this with surprise; but as it was not to be accounted for from tried common principles, we could

[1] Fletcher's Rudiments of Physiology, P. ii. *a*., p. 52, Edinb., 1836.
[2] Tract. de Homine, p. 167, Amst., 1677.
[3] Ortus Medicin. &c., Amstel., 1648.
[4] Theoria vera Medica, Hal., 1737.
[5] Physiol. de l'Homme, edit. cit., iii. 302.
[6] Treatise on Nervous Diseases, p. 307.

hardly believe the fact as he related it, much less give any account of it; unless he should please to make the experiment before us, which we were unwilling he should do, lest, in his weak condition, he might carry it too far. He continued to talk very distinctly and sensibly above a quarter of an hour, about this (to him) surprising sensation, and insisted so much on our seeing the trial made, that we were at last forced to comply. We all three felt his pulse first; it was distinct, though small and thready; and his heart had its usual beating. He composed himself on his back, and lay in a still posture some time. While I held his right hand, Dr. B. laid his hand on his heart, and Mr. S. held a clean looking-glass to his mouth. I found his pulse sink gradually, till at last I could not feel any, by the most exact and nice touch. Dr. Baynard could not feel the least motion in his heart, nor Mr. Skrine the least soil of breath on the bright mirror he held to his mouth. Then each of us, by turn, examined his arm, heart and breath, but could not by the nicest scrutiny discover the least symptom of life in him. We reasoned a long time about this odd appearance as well as we could; and all of us judging it inexplicable and unaccountable; and finding he still continued in that condition, we began to conclude indeed that he had carried the experiment too far, and at last were satisfied that he was actually dead, and were just ready to leave him. This continued about half an hour, by nine o'clock in the morning, in autumn. As were going away, we observed some motion about the body, and upon examination found his pulse and the motion of his heart gradually returning; he began to breathe gently, and speak softly; we were all astonished, to the last degree, at this unexpected change, and after some further conversation with him, and among ourselves, went away fully satisfied as to all the particulars of this fact, but confounded and puzzled, and not able to form any rational scheme, that might account for it. He afterwards called for his attorney, added a codicil to his will, settled legacies on his servants, received the sacrament, and calmly and composedly expired about five or six o'clock that evening."

It is manifest that this case—unaccountable as it is, in many respects —can add no weight to the views of the Stahlians. It is as strange, as it is inexplicable. The opinion, with them, that the heart's action is a muscular function was accurate. The error lay in placing it amongst the voluntary functions. It belongs to the involuntary class, equally with many of the muscles concerned in deglutition, and those of the stomach and intestines; and how well is it for us, as Sir Charles Bell has remarked, that its action as well as that of other organs directly instrumental to the organic functions is placed out of our control! "A doubt—a moment's pause of irresolution—a forgetfulness of a single action at its appointed time—would otherwise have terminated our existence."

In an oriental journal, Mr. H. M. Twedel[1] published a case even more extraordinary than that of Col. Townshend,—of a Hindoo, thirty years of age, who "is said, by long practice, to have acquired the art of holding his breath, by shutting the mouth, and stopping the interior opening of the nostrils with the tongue." This man submitted to be

[1] India Journal of Medical and Physical Sciences; cited in Amer. Journ. of the Medical Sciences, p. 250, Nov., 1837.

buried for a month, and was dug out alive at the expiration of that period. "He was taken out in a perfectly senseless state—his eyes closed; his hands cramped and powerless; his stomach shrunk very much, and his teeth jammed so fast together, that they were forced to open his mouth with an iron instrument to pour a little water down his throat. He gradually recovered his senses, and the use of his limbs, and was restored to perfect health"!

The doctrine of Haller[1] on the heart's action rested upon the *vis insita* or *irritability* to which he referred all muscular contractions, voluntary and involuntary. This property, as stated in another place, he conceived to be possessed by muscles as muscles, independently of all nervous influence. The heart, being a muscle, enjoyed it of necessity; and the irritant, that incessantly developed it, was the blood. In evidence of this, he observes, that its contractions are always more forcible and rapid, when the blood is more abundant; and that they occur successively in the cavities of the heart as the blood reaches them. So wholly did Haller assign the heart's action to this irritability, that he denied the nerves any influence over it; resting his belief on the admitted facts,—that it will continue to beat after decapitation; after the division of the spinal marrow in the neck; and of the nerves distributed to the organ; and, even after it has been entirely removed from the body. How far the opinions of this great man are correct, respecting the power of contraction residing in the heart, as he conceived it to do in other muscles, we shall inquire presently. It is, however, doubtless, indirectly, under the nervous influence. We see it affected in the various emotions; sometimes augmenting violently, at others, retarding its action. These circumstances have led some to adopt a kind of intermediate opinion, and to regard the nervous influence as one of the conditions necessary for all muscular contraction, just as the due circulation of blood is; and to admit, at the same time, the separate existence of a *vis insita*. Sömmering[2] and Behrends[3] have, indeed, asserted that the cardiac nerves are not distributed to the tissue of the heart, but merely to the ramifications of the coronary arteries; and hence, that these nerves are not concerned in the motions of the organ, but only in its nutrition: but this special distribution is denied by Scarpa,[4] and the generality of anatomists.

Although the emotions manifestly affect the heart, direct experiments exhibit but little influence over it on the part of the nerves. This, indeed, we have seen, is one of the grounds for the doctrine of Haller. Willis[5] divided the eighth pair of nerves; yet the action of the heart persisted for days. Similar results followed the section of the great sympathetic. M. Magendie[6] states, that he removed, on several occasions, the cervical ganglions, and the first thoracic; but was unable to determine anything satisfactory from the operation, in consequence of the immediate death of the animal from such extensive injury. He observed, however, no direct influence on the heart.

[1] Op. citat. [2] Corpor. Human. Fabric., iii. § 32.
[3] Dissert. quâ Demonstrat. Cor. Nervis Carere, Mogunt., 1792; and in Ludwigii Script. Neurol. Min., i. 1. [4] Tabulæ Neurologicæ, &c., Ticin., 1794.
[5] Cerebri Anat., cap. xxiv. in Oper., Genev., 1776. [6] Précis, &c., ii. 401.

We have numerous examples of the comparative independence of the organ, as regards the encephalon. Decapitated reptiles have lived for months; and anencephalous infants, or those born with part of the brain only, have vegetated during the whole period of pregnancy, and for some days after birth. M. Legallois[1] kept several decapitated mammalia alive; and maintained the heart in action, (having taken the precaution to tie the vessels of the neck for the purpose of preventing hemorrhage,) by employing artificial respiration, so as to keep up the conversion of venous into arterial blood, and thus insure to the heart a supply of its appropriate fluid. We find, too, that in fracture of the skull, in apoplexy, and congenerous affections, the functions of the heart are the last to be arrested. The result of his own experiments led Legallois to infer, that the power of the heart is altogether derived from the spinal marrow; and he conceived, that through the cardiac nerves it is influenced by that portion of the cerebro-spinal axis, and is liable to be affected by the passions because the spinal marrow is itself influenced by the brain. Dr. Wilson Philip[2] has, however, shown, that the facts do not warrant the conclusions; and has exhibited, by direct experiment, that the brain has as much influence as the spinal marrow over the motions of the heart, when the circumstances of the experiment are precisely the same. The removal of the spinal marrow, like that of the brain, if the experiment be performed cautiously and slowly, does not sensibly affect the motion of the organ,—the animal having been previously deprived of sensibility. In these experiments, the circulation ceased quite as soon without, as with, the destruction of the spinal marrow. Loss of blood appeared to be the chief cause of its cessation; and pain would have contributed to the same effect, if the animal had been operated on, without having been previously rendered insensible.

Mr. Clift,[3] the former conservator of the Museum of the Royal College of Surgeons of London, made a series of experiments to ascertain the influence of the spinal marrow on the action of the heart in fishes, and found, that its action continues long after the brain and spinal marrow are destroyed, and still longer when the brain is removed without injury to its substance. Similar results were obtained by Treviranus on the frog, and by Saviole on the chick in ovo. Zinn and Ent, too, found, that after the destruction of the cerebellum, to which Willis ascribed its action, it continued to beat.

All these facts plainly exhibit, that, although the heart is *indirectly* influenced by the brain or spinal marrow, it is not *directly* acted upon by either one or the other, and that its action can be maintained for some time after the destruction of one or both, provided artificial respiration be kept up; and even this is unnecessary: it will continue to beat after it has been removed from the body. Dr. Dowler, of New Orleans,[4] saw the heart of the alligator beat for seven hours when its "annexing vessels" had been separated. In the case of the rattlesnake, Dr. Har-

[1] Sur le Principe de la Vie, p. 138.
[2] An Experimental Inquiry into the Laws of the Vital Functions, &c., p. 62, Lond., 1817.
[3] Philosoph. Transact. for 1815.
[4] Contributions to Physiology, p. 17, New Orleans, 1849.

lan[1] observed it, torn from the body, continue its contractions for ten or twelve hours; and in the monstrous fœtus, described by Dr. T. Robinson,[2] its motion continued for some time after the auricles and ventricles had been laid open; the organ roughly handled, and thrown into a basin of cold water. We are compelled, then, if we do not admit the whole of the Hallerian doctrine of irritability, to presume, that there is something inherent in the structure of the heart, which enables it to contract and dilate, when appropriately stimulated; and it is not even necessary that this should be by the fluid to which it is habituated. It is certain, that the organ, when separated from the body, may be stimulated to contraction, by being immersed in warm water, or pricked with a sharp-pointed instrument. In some experiments by Sir B. Brodie,[3] the heart was emptied of its blood, and still contracted and relaxed alternately. Similar experiments were instituted by Mr. Mayo,[4] and with like results,—from which he concludes, that the alternations of contraction and relaxation of the heart depend upon something in its structure. The conclusion seems, indeed, irrefutable, if we add to these evidences the results of certain experiments of Dr. J. Wiltbank,[5] and of Dr. J. K. Mitchell. After the brain and medulla spinalis of the *Testudo serpentaria*, *snapping-turtle* or *snapper* had been destroyed, the heart continued to beat for thirty-two hours and upwards. In 1823, Dr. Mitchell,[6] being engaged in dissecting a sturgeon—*Acipenser brevirostrum?*—took out its heart and laid it on the ground. After a time, it ceased to beat and was inflated with the breath, for the purpose of being dried. Hung up in this state, it began again to move, and continued for ten hours to pulsate regularly, though more and more slowly; and when last observed in motion, the auricles had become so dry as to rustle when they contracted and dilated. He subsequently repeated the experiment with the heart of a *Testudo serpentaria*, and found it to beat well under the influence of oxygen, hydrogen, carbonic acid, and nitrogen, thrown into it in succession. Water also stimulated it,—perhaps more strongly,—but made its substance look pale and hydropic, and, in *one minute*, destroyed action beyond recovery. A few years ago, (1845,) Dr. Mitchell repeated the experiment with the sturgeon, with the like results; and soon afterwards, Dr. F. G. Smith, junior,[7] experimented on the hearts of the sturgeon, frog, and snapping-turtle. The heart of one sturgeon contracted for twenty-two hours after its removal from the body; of another twelve hours; of the frog thirteen hours; and of the snapping-turtle for 25¾ hours. The contractions of the last were arrested by putting the organ in warm water with the hope of increasing them. The heart of a sturgeon inflated by Dr. Smith, and kindly sent by him to the author, hung up in his library and kept moist, contracted and dilated for upwards of twenty hours.

[1] Medical and Physical Researches, p. 103, Philad., 1835.
[2] Amer. Journ. of the Med. Sciences, No. xxii., Feb., 1833.
[3] Cooke's Treatise on Nervous Diseases, Introd. p. 61, Lond., 1820–23, Amer. edit., Boston, 1824.
[4] Outlines of Human Physiology, 4th edit., p. 46, Lond., 1837.
[5] The Philadelphia Journal of the Medical and Physical Sciences, ix. 361, Philad., 1824.
[6] American Journal of the Medical Sciences, vii. 58, Philad., 1830.
[7] Letter to the author, in Philadelphia Medical Examiner, for July, 1845, p. 393.

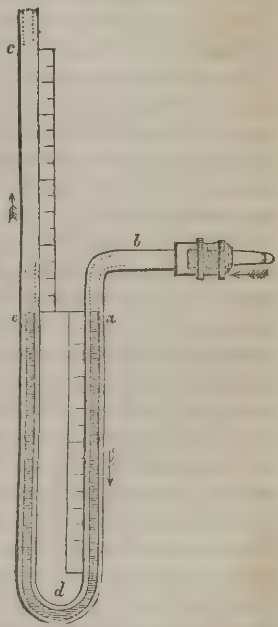
It has been supposed, that when the heart was empty of blood, the contact of air with its cavities is the stimulus by which its irritability is excited, but Dr. John Reid[1] found, as Caldani, Wernlein and Kürschner had already done, when he placed a frog's heart in a state of activity under the receiver of an air-pump, that its action still continued after the receiver had been exhausted. More recent experiments, however, by F. Tiedemann[2] do not accord, in their results, with those of Dr. Reid; but confirm those of Fontana. He placed the heart, immediately after it was removed from a living frog, under the receiver of an air-pump, from which he exhausted the air: the pulsations of the heart became weaker and slower, and in thirty seconds ceased. After five minutes, the air was readmitted, and the pulsations were resumed; and this alternation was repeated several times; whilst another heart, suspended in air, continued in uninterrupted action for an hour. These experiments were repeated at the request of the author during the winter of 1849–50, by Drs. S. Weir Mitchell, and T. H. Bache; with analogous results. When the density of the air was augmented under the receiver, M. Tiedemann found, that the pulsations became quicker and stronger.

The heart is the generator of one of the forces that move the blood. This force has been the subject of much calculation, but the results have been so discordant as to throw discredit upon all mathematical investigations on living organs; a circumstance, which renders it unnecessary to state the different plans that have been pursued in these estimations. Many of them are given in the elaborate work of Haller,[3] to which the reader, who may be desirous of examining them, is referred. Borelli[4] conceived the force exerted by the left ventricle to be equivalent to 180,000 pounds; Sénac[5] to 40; Hales[6] to 51·5 pounds; Jurin[7] to 15 pounds 4 ounces; whilst Keill[8] conceived it not to exceed from 5 to 8 ounces! The mode adopted by Hales has always been regarded the most satisfactory. By inserting a glass tube into the carotid of various animals, he noticed how high the blood rose in the tube. This he found to be, in the dog, 6 feet 8 inches; in the ram, 6 feet $5\frac{1}{2}$ inches; in the horse, 9 feet 8 inches; and he estimated that in man it would rise as high as $7\frac{1}{2}$ feet. Now, a tube, whose area is one inch square and two feet long, holds nearly a pound of water. We may therefore reckon the weight, pressing on each square inch of the ventricle, to be, on a rough estimate, three pounds and three-quarters, or four pounds; and if we consider, with Michelotti, the surface of the left ventricle to be fifteen square inches, it will exert a force, during its contraction, capable of raising sixty pounds. Its extent is more frequently, however, estimated at 10 square inches, and the force developed

[1] Cyclop. of Anat. and Physiol., ii. 611, Lond, 1839.
[2] Müller's Archiv. für Anatomie, u. s. w., s. 490, Berlin, 1847.
[3] Elementa Physiologiæ, lib. i. sect. iv. § 42, Lausann., 1757.
[4] De Motu Animalium, pars ii., Lugd. Bat., 1710.
[5] Traité de la Structure du Cœur, Paris, 1749.
[6] Statical Essays, &c., ii. 40, Lond., 1733.
[7] Philosophical Transactions for 1718 and 1719.
[8] Tentamina Medico-Physica, &c., Lond., 1718.

would therefore, be forty pounds;[1] but this is, of course, a rude approximation. In such a deranging experiment, the force of the heart cannot fail to be modified; and it is so much affected by age, sex, temperament, idiosyncrasy, &c., that the attainment of accurate knowledge on the subject is impracticable. The indefinite character of our information on this matter is indeed sufficiently shown by the investigations of M. Poiseuille,[2] which led him to suppose, that the force with which the organ propels the blood into the human aorta is about 4 pounds, 3 ounces, and 43 grains, and if Valentin's estimate of the muscular force of the right ventricle being one-half that of the left be taken, it must propel the blood into the lungs with a force only equal to about two pounds, two ounces. By means of an instrument, which, from its use, he terms *hæmadynamometer*, M. Poiseuille has endeavoured to show, that the blood is urged forward with as great a momentum in a small artery, far from the heart, as in any important branch near it. In other words, that there is a uniform amount of pressure exerted by the blood upon the coats of the arteries in every part of the body;—those in the immediate vicinity of the heart being distended by an equal force with those most remote from it. M. Poiseuille[3] made the experiment on the carotid, and muscular branch of the thigh of the horse; and notwithstanding the very great dissimilarity in the diameter of the two tubes, and in their distance from the heart, the displacement of the mercury was exactly the same in both. This inference, if correct,—and the experiments have been repeated by M. Magendie[4] and others with corresponding results,—is important in a therapeutical point of view, as it leads to the belief, that if it be desirable to lessen the quantity of the circulating fluid, it is of little consequence what vessel is opened. The hæmadynamometer employed by M. Poiseuille, consists of a bent glass tube, of the form represented in the marginal figure, filled with mercury in the lower bent part, *a*, *d*, *e*. The horizontal part *b*, provided with a brass head, is fitted into the artery, and a small quantity of a solution of carbonate of soda is interposed between the mercury and the blood, which is allowed to enter the tube with the view of preventing coagulation. When the blood is allowed to press upon the fluid in the horizontal limb, the rise of the mercury

Fig. 297.



Hæmadynamometer.

[1] Arnott's Elements of Physics, Amer. edit., pp. 447 and 461, Philad., 1841.
[2] Magendie's Journal de Physiologie, x. 241.
[3] Ibid., ix. 46.
[4] Leçons sur le Sang, &c., or translation in Lond. Lancet, Sept. 1838 to March, 1839; and in Bell's Select Medical Library, p. 57, Philad., 1839.

towards *e*, measured from the level to which it has fallen towards *d*, gives the pressure under which the blood moves.

Estimates by Valentin[1] as to the force of the heart make it even less than those of M. Poiseuille. He states, that in man and the higher mammalia, the absolute force exerted by the left ventricle is equal to $\frac{1}{50}$th of the weight of the body; and that by the right ventricle equal to $\frac{1}{100}$th of the same.

During the diastole of the ventricles, the pressure, as indicated by the instrument, is somewhat diminished. It was observed by Hales,[2] that the column of blood in a tube inserted into an artery fell after each pulsation. The pressure must obviously be augmented or diminished by anything that adds to or detracts from the heart's action; and it will be seen afterwards, that it is materially modified by the respiratory movements.[3]

b. *Circulation in the Arteries.*

The blood, propelled from the heart by the series of actions we have described, enters the two great bloodvessels;—the pulmonary artery from the right ventricle, and the aorta from the left; the former of which sends it to the lungs, the latter to every part of the system; and, in both vessels, it is prevented from returning into the corresponding ventricles by the depression of the semilunar valves. We have now to inquire into the circumstances, that act upon it in the arteries, and whether it be the contraction of the ventricle, which is alone concerned in its progression.

Harvey[4] and all the mechanical physiologists regarded the arteries as entirely passive in the circulation, and as acting like so many lifeless tubes; the heart being, in their view, the sole agent. We have, however, numerous reasons for believing that the arteries are concerned to a certain degree in the progression of the blood. If we open a large artery in a living animal, the blood flows in distinct pulses; but this effect gradually diminishes as the artery recedes from the heart, and ultimately ceases in the smallest ramifications;—seeming to show, that the force, exerted by the heart, is not the only one concerned. It is manifest, too, that if such was the case, the blood ought to flow out of the aperture, when the artery is opened, at intervals coinciding with the contractions of the organ; and that during the diastole of the artery no blood ought to issue. This, however, is not the case, notwithstanding the authority of Bichat and some others is in its favour. The flow is uninterrupted; but in jets or pulses, coinciding with the contractions of the ventricles. Again, if two ligatures be put round an arterial trunk, at some distance from each other, and a puncture be made between the ligatures, the blood flows with a jet,—indicating that compression is exerted upon it; and if the diameter of the artery be measured with a pair of compasses, before and after puncturing the vessel, it will be found manifestly smaller in the latter case;—an ex-

1 Lehrbuch der Physiologie des Menschen, i. 415, Braunschweig, 1844.
2 Op. cit., ii. 2.
3 Ludwig, in Müller's Archiv. für Anatomie, u. s. w., Heft iv. s. 242, Berlin, 1847.
4 Exercitatio Anat. De Motu Çordis et Sanguinis, &c., Rotterd., 1648.

periment which shows the fallacy of a remark of Bichat,—that the force with which the arteries return upon themselves is insufficient to expel the blood they contain. An experiment of M. Magendie[1] exhibits this more clearly. He exposed the crural artery and vein in a dog, and passed a ligature behind the vessels, tying it strongly at the posterior part of the thigh, so that the blood could only pass to the limb by the artery, and return by the vein. He then measured, with a pair of compasses, the diameter of the artery; and on pressing the vessel between his fingers, to intercept the course of blood, it was observed to diminish perceptibly in size below the part compressed, and to empty itself of its blood. On readmitting the blood, by removing the fingers, the artery became gradually distended at each contraction of the heart, and resumed its previous dimensions.

These facts prove, that the arteries contract; but the kind of contraction has given occasion to discussion. Under the idea that their middle coat is muscular, it was conceived formerly, that they exert a similar action on the blood to that of the heart; dilating to receive it from that organ, and contracting to propel it forwards;—their systole being synchronous with that of the auricles and the diastole of the ventricles, and their diastole with that of the auricles and the systole of the ventricles. The principal reasons urged in favour of this view are;—the fact of the circulation being effected solely by the arteries in acardiac fœtuses, and in animals that have no heart;—the assertion of MM. Lamure and Lafosse, that they noticed, in an experiment on the carotid artery, similar to that described above, that the vessel continued to beat between the ligatures;—the affirmations of Verschuir,[2] Bikker, Giulio, and Rossi,[3] Thomson,[4] Parry,[5] Hastings,[6] Wedemeyer, and numerous others, that when they irritated arteries with the point of a scalpel, or subjected them to the electrical and galvanic influences, they exhibited manifest contractility; and lastly, the fact, that the pulse is not perfectly synchronous in different parts of the body, which ought to be the case, were the arteries not possessed of distinct action.

The chief objection to the views founded on the muscularity of the middle coat was the want of evidence of the fact. In the anatomical proem to the function of the circulation it was stated, that this coat had not seemed to anatomists to consist of fibrous or muscular tissue; and that the experiments of MM. Magendie, Nysten, and others, had not been able to exhibit any contraction, on the application to it of the ordinary excitants of muscular irritability. The chemical analyses of Berzelius[7] and Young[8] also appeared to show, that the transverse fibres differ essentially from those of proper muscles. It has been suggested, however, that the older analyses may have been made on the largest

[1] Journal de Physiologie, i. 111; and Précis, &c., ii. 386.
[2] De Arteriar. et Venar. Vi Irritabili, &c., Gröning., 1766.
[3] Elémens de Médec. Opérat., Turin, 1806.
[4] Lectures on Inflammation, p. 83, Edinb., 1813; also, 2d Amer. edit., Philad., 1831.
[5] On the Arterial Pulse, p. 52, Bath, 1816.
[6] On Inflammation of the Mucous Membrane of the Lungs, p. 20, Lond., 1820.
[7] View of the Progress of Animal Chemistry, p. 25, Lond., 1813.
[8] An Introduction to Medical Literature, p. 501, Lond., 1813.

arteries in which muscular fibres scarcely exist;[1] for histologists—as elsewhere shown—are now agreed, that, in the smaller arteries, more especially, the middle coat is partly composed of nonstriated or unstriped muscular tissue. Moreover, if any doubt existed in regard to the contractile action of the smaller arteries, it ought to be removed by the experiments of MM. E. and E. H. Weber,[2] accurate observers, which were made with the rotating magneto-electric apparatus upon the arteries of the mesentery of frogs between $\frac{1}{7}$th and $\frac{1}{17}$th of a Paris line in diameter. When vessels between these dimensions were exposed to the electric stream they did not immediately respond to the irritation; but in a few seconds they began to contract, so that in from five to ten seconds their diameter was diminished one-third. If the stimulus was continued, the diminution of size went on until the diameter was reduced to one-third or even one-sixth of what it was originally, so that only a single row of blood corpuscles could pass along the vessel, and at last became completely closed unless the stimulus was removed. They found, however, no change produced in the capillaries when the magneto-electric current was applied to them; but it appeared to cause an unusual adhesion of the corpuscles to each other, and to the parietes of the vessels, and a consequent stagnation of the circulating fluid in them. Nor did the larger arteries exhibit any signs of contraction when the stream was directed to them.

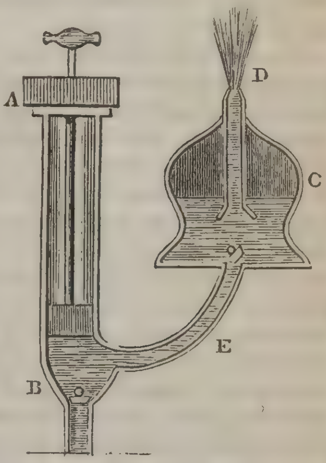
If an artery be exposed in a living animal, we observe none of that contraction and dilatation which is perceptible in the heart; although a manifest pulsation is communicated to the finger placed over it. The phenomena of the pulse will engage attention speedily. We may merely remark, at present, that the pulsations are manifestly more dependent upon the action of the heart than upon that of the arteries. In syncope, they entirely cease; and whilst they continue beneath an aneurismal tumour, because the continuity of the vessel is not destroyed, they completely cease beneath a ligature so applied around an artery as to cut off the flow of blood. Bichat attached an inert tube to the carotid artery of a living animal, so that the blood could flow through it: the same kind of pulsation was observed in it as in the artery. To this he adapted a bag of gummed taffeta, so as to simulate an aneurismal tumour: the pulsations were evidenced in the bag. If, again, arterial blood be passed into a vein, the latter vessel, which has ordinarily no pulsation, begins to beat; whilst, if blood from a vein be directed into an artery, the latter ceases to beat.[3]

Another class of physiologists have reduced the whole of the arterial action to simple elasticity; a property, which the yellow tissue that composes the proper membrane of the artery seems to possess in an unusual degree. Such is the opinion of M. Magendie.[4] "Admitting it to be certain," he remarks, "that contraction and dilatation occur in arteries, I am far from thinking, with some authors of the last century,

[1] Kirkes and Paget, Manual of Physiology, p. 91, Amer edit., Philad., 1849.
[2] Müller's Archiv. für Anatomie, u. s. w., H. ii. s. 282, Jahrgang, 1847.
[3] Adelon, art. Circulation, in Dict. de Médecine, 1ère édit., v. 321, Paris, 1822, and Physiol. de l'Homme, edit. cit., iii. 380.
[4] Précis, &c., edit. cit., ii. 387

that they dilate of themselves, and contract in the manner of muscular fibres. On the contrary, I am certain, that they are passive in both cases,—that is, that their dilatation and contraction are the simple effect of the elasticity of their parietes, put in action by the blood, which the heart sends incessantly into their cavity,"—and he farther remarks, that there is no difference, in this respect, between the large and small arteries. As regards the larger arteries, it is probable that this elasticity is the principal but not the only action exerted; and that it is the cause why the blood flows in a continuous, though pulsatory, stream, when an opening is made into them; thus acting like the reservoir of air in certain pumps. In the pump A B, represented in the marginal figure, were there no air-vessel C, the water would flow through the pipe E at each stroke of the piston, but the stream would be interrupted. By means of the air-vessel this is remedied. The water, at each stroke, is sent into the vessel; the air contained in the air-vessel is thus compressed, and its elasticity thereby augmented; so that it keeps up a constant pressure on the surface of the water, and forces it out of the vessel through the pipe D in a nearly uniform stream.—Now, in the heart, the contraction of the ventricle acts like the depression of the piston; the blood is propelled into the artery in an interrupted manner, but the elasticity of the blood-vessel presses upon the blood, in the same manner as the air in the air-vessel presses upon the water within it; and the blood flows along the vessel in an uninterrupted, although pulsatory, stream. There are many difficulties, however, in the way of admitting the whole of the action of the arteries in the circulation to be dependent upon simple elasticity. The heart of a salamander was opened by Spallanzani;[1] the blood continued to flow through the vessels for twelve minutes after the operation. The heart of a tadpole was cut out; the circulation was maintained for some time in several of the vascular ramifications of the tail. The heart of the chick in ovo was destroyed immediately after contraction; the arterial blood took a retrograde direction, and the momentum of the venous blood was redoubled. The circulation continued in this manner for eighteen minutes. Dr. Wilson Philip[2] states, that he distinctly saw the circulation in the smaller vessels, for some time after the heart had been removed from the body, and a similar observation was made by Dr. Hastings.[3] The latter gentleman states, that in the large arterial trunks, and even in the veins, he has

Fig. 298.



Section of a Forcing Pump.

[1] Experiments on the Circulation, &c., translated by R. Hall, Lond., 1801.

[2] An Experimental Inquiry into the Laws of the Vital Functions, Lond., 1817; and Lond. Med. Gazette, for March 25th, 1837, p. 952.

[3] Op. citat., p. 51.

noticed, in the clearest manner, their contraction on the application of various stimulants, both chemical and mechanical. It is, moreover, well known, that if a small living artery be cut across, it soon contracts so as to arrest the hemorrhage;—that whilst an animal is bleeding to death the arteries will accommodate themselves to the decreasing quantity of blood in the vessels, and contract beyond the degree to which their elasticity could be presumed to carry them; and that after death they will again relax. Dr. Parry found, that an artery of a living animal, if exposed to the air, sometimes contracts in a few minutes to a great extent; in such case, only a single fibre of the artery may be affected, narrowing the channel in the same way as if a thread were tied round it.

The experiments that have been instituted for the purpose of discovering the dependence of the arterial action on the nervous system have likewise afforded evidences of their capability of assuming a contractile action, and have led to a better comprehension of cases of what have been called local *determinations* of blood. Dr. Philip found, that the motion of the blood in the capillaries is influenced by stimulants applied to the central parts of the nervous system, which must be owing to these vessels, possessing a power of contractility, capable of being aroused to action by the nervous influence. The experiments of Sir Everard Home[1] are, however, more applicable, as they were directed to the larger arteries, respecting which the greatest doubts have been entertained. The carotid artery of a dog was laid bare; the par vagum and great sympathetic, which, in that animal, form one bundle, were separated from it by a flattened probe for one-tenth of an inch in length; the head and neck of the dog were then placed in an easy position, and the pulsations of the carotid artery were attended to by all present for two minutes, in order that the eye might be accustomed to their force in a natural state. The nerve passing over the probe was then slightly touched with caustic potassa. In a minute and a half, the pulsations of the exposed artery became more distinct. In two minutes, the beats were stronger; in four minutes, their violence was lessened; and in five minutes the action was restored to its natural state. The experiment was repeated with analogous results upon a rabbit. The par vagum was separated from the intercostal nerve; and when the former nerve alone was irritated no increase took place in the force of the action of the artery. "The carotid artery," says Sir Everard, "was chosen as the only artery in the body of sufficient size, that can be readily exposed, to which the nervous branches, supplying it, can be traced from their trunk. This experiment was repeated three different times, so as to leave no doubts respecting the result." These experiments demonstrate, that, under the nervous influence, an increase or a diminution may take place in the contraction of an artery; and they aid us in the explanation of cases, in which the circulation has been accomplished where the heart has been altogether wanting or completely defective in structure. Sir Everard instituted farther experiments, with the view of determining whether heat or cold has the

[1] Lectures on Comparative Anatomy, iii. 57, Lond., 1823.

greater agency in stimulating the nerves to produce this effect upon the artery. The wrist of one arm was surrounded by bladders filled with ice; and after it had remained in that state for five minutes, the pulse of the two wrists was felt at the same time. The beats in that which had been cooled were found to be manifestly stronger. A similar experiment was now made with water, heated to from 120° to 130° of Fahrenheit. The pulse was found to be softer and feebler in the heated arm. When one wrist was cooled and the other heated, the stroke of the pulse of the cooled arm had much greater force than that of the heated one. These experiments were repeated upon the wrists of several young men and young women of different ages, with uniform results.

Lastly, we have remarked, and shall have occasion to refer to the matter again, that certain animals, that have no heart, have circulating vessels in which contraction and dilatation are perceptible. This is the case with the class *vermes* of Cuvier, and distinctly so in the *lumbricus marinus* or *lug*, the *leech*, &c. The fact has been invoked both by the believers in the muscular contractility of arteries, and by those who conceive the contractility to be peculiar; but our acquaintance with the intimate structure of the coats of the vessels in those animals is too imperfect for us to assert more than that they are manifestly contractile. In an interesting case of a cardiac fœtus examined by Dr. Houston, of Dublin, it seemed impossible that the heart of a twin fœtus could have occasioned the movement of blood in the acardiac one; and hence that there must have been some power in the vessels of the latter—general, or capillary, or both—to effect the circulation through it. In most or all of these cases, however, a perfect twin fœtus exists, whose placenta is in some degree united with that of the imperfect one; and the circulation in the latter has usually been attributed to the influence of the heart of the former propagated through the placental vessels.

From these and other considerations, the majority of physiologists have admitted a contractile action, in perhaps all except the larger arterial trunks; and, at the present day, the most general and satisfactory opinion appears to be, that, in addition to the highly elastic property possessed by the middle coat, it is capable of being thrown into contraction by the organic muscular fibres, which exist in larger quantities in the smaller arteries than in the larger; that, consequently in the larger vessels this contraction is little evidenced, the action of the artery being mainly produced by its elasticity; but that, in the smaller arterial ramifications, the contractility is more manifest; its great object being to regulate the quantity of blood to be distributed to a part; or to adjust the vessel to the amount of fluid circulating in it. To this contractility, necessarily connected with the life of the vessel, and which he considered to differ from both muscular contractility and simple elasticity, Dr. Parry[1] gave the name *tonicity*.

c. *Circulation through the Capillaries.*

The agency of the capillary vessels in the circulation has been a

[1] On the Arterial Pulse, p. 52, Bath, 1816.

subject of contention. The opinion of Harvey, embraced by J. Müller,[1] was, that the action of the heart alone is sufficient to send the blood through the whole circuit; but we have seen, that, even when aided by the elasticity and contractility of the arterial trunks, the pulsations of that organ become imperceptible in the smaller arteries; and, hence, there is some show of reason for the belief, that in the capillary vessels the force may be entirely spent. Were we, indeed, to admit that the force of the heart is sufficient to send the blood through a single capillary circulation, it would be difficult to admit that it could send it through two—as in the portal circulation. Still, we can by no means accord with Professor Draper,[2] of New York, that "it is now on all hands conceded," that this powerful muscular organ—the heart—discharges "a very subsidiary duty."

Bichat regarded the capillaries as organs of propulsion, and alone concerned in returning the blood to the heart through the veins. Dr. Marshall Hall,[3] on the other hand, denies, that we have any proof of irritability in the true capillaries; and Magendie[4] conceives the contraction of the heart to be the principal cause of the passage of the blood through those vessels. In support of this view he adduces the following experiment. Having passed a ligature round the thigh of a dog, so as not to compress the crural artery or vein, he tied the latter near the groin, and made a small opening into the vessel. The blood immediately issued with a considerable jet. He then pressed the artery between the fingers, so as to prevent the arterial blood from passing to the limb. The jet of venous blood did not, however, stop. It continued for some moments, but went on diminishing, and the flow was arrested, although the vein was filled through its whole extent. When the artery was examined during these occurrences, it was observed to contract gradually, and at length became completely empty when the course of the blood in the vein ceased. At this stage of the experiment, the compression was removed from the artery; the blood immediately passed into the vessel, and, as soon as it had reached the final divisions, began to flow again through the opening in the vein, and the jet was gradually restored. On compressing the artery again until it was emptied, and afterwards allowing the arterial blood to pass slowly along the vessel, the discharge from the vein took place, but without any jet: the jet was resumed, however, as soon as the artery was entirely free.

This experiment is not so convincing to us as it appears to have been to M. Magendie. The chief fact, which it exhibits, is the elastic, and probably contractile, power of the arteries. It might have been expected, *à priori*, under any hypothesis, that the quantity of blood discharged from the vein would hold a ratio to that sent by the artery; and, consequently, the experiment appears to us to bear but little on the question regarding the separate contractile action of the capillaries.

[1] Handbuch, u. s. w., Baly's translation, p. 220, Lond., 1838.
[2] A Text-Book on Chemistry, p. 392, New York, 1846.
[3] A Critical and Experimental Essay on the Circulation, &c., p. 78, Lond., 1831, reprinted in this country, Philad., 1835.
[4] Précis, &c., ii. 390.

It is difficult, indeed, to believe that such an action does not exist. In addition to the circumstance, already mentioned, of the absence of pulsation in the smaller arteries, almost every writer on the theory of inflammation considers the fact of a distinct action of the capillaries established, and leaves to the physiologist the by no means easy task of proving it. Dr. Wilson Philip[1] placed the web of a frog's foot under the microscope, and distinctly saw the capillaries contract on the application of those stimulants that produce contraction of the muscular fibre. The results of Dr. Thomson's[2] experiments in investigating inflammation, as well as those of Dr. Hastings,[3] were the same. The facts, already referred to, regarding the continuance of the circulation in the minute vessels after the heart has been removed, as well as the observation of Dr. Philip, that the blood in the capillaries is influenced by stimulants applied to the central parts of the nervous system, are confirmatory of the same point. The experiments of Drs. Thomson, Philip, and Hastings, were repeated by Wedemeyer,[4] with great care. The circulation in the mesentery of the frog, and in the web of its foot, being observed through the microscope, it was evident, that no change occurred in the diameter of the small arteries, or in that of the capillaries, so long as the circulation was allowed to go on in its natural state; but as soon as excitants were applied to them, an alteration of their calibre was perceptible. Alcohol arrested the flow of blood without inducing much apparent contraction of the vessels. Chloride of sodium, in the course of three or four minutes, caused them to contract one-fifth of their calibre, which was followed by their dilatation, and a gradual retardation and stoppage of the blood. In a space of time varying from ten to thirty seconds, and sometimes immediately after the application of the galvanic circle, they contracted, some one-fourth, others one-half, and others three-fourths of their calibre. The contraction at times continued for a considerable period, occasionally for several hours; in other instances it ceased in ten minutes, and the vessels resumed their natural diameter. A second application of galvanism to the same capillaries seldom caused any material contraction. Schwann[5] likewise found, that when cold water was poured on the vessels of a frog, which had been previously in a warm atmosphere, the capillaries immediately contracted, but after a time regained their diameter. Farther, Mr. Hunter[6] found, on exposing arteries to the air, that they contracted so much as to occasion obliteration of their cavities, and it is well known, that when arteries—as the temporal—are divided, the hemorrhage is arrested by the spontaneous contraction of the divided vessel,—a contraction, which, as remarked by Dr. Carpenter, is much greater than could be accounted for by simple elasticity of tissue, and is more marked in small than in large vessels.[7]

[1] A Treatise on Febrile Diseases, 3d edit., ii. 17, London, 1813; and Medico-Chirur. Transact., vol. xii. p. 401.

[2] Lectures on Inflammation, p. 83, Edinb., 1813.

[3] Op. citat.

[4] Untersuch, über die Krieslauf, u. s. w., Hannover, 1828; cited in Edinb. Med. and Surg. Journ., vol. xxxii.

[5] Müller's Archiv, 1836, and Lond. Med. Gazette, May, 1837.

[6] A Treatise on the Blood, Inflammation, and Gunshot Wounds, Amer. edit., ii. 156, Philad., 1840.

[7] Human Physiology, § 502, Lond., 1842.

All these facts prove the existence of a vital power in the capillaries, capable of modifying, to a considerable extent, the flow of blood through them.

Again:—of this independent action of the capillary vessels we have, every day, proofs in local inflammation; in which there may be increased redness of a part, without the general circulation exhibiting the slightest evidences of augmented action or excitement. In the natural state, the vessels of the tunica conjunctiva covering the white of the eye receive little blood; but if any cause of irritation exists, as a grain of sand entering between the eyelids, we find blood rapidly sent into them, giving the appearance that has been not inappropriately termed "blood-shot."[1] In the experiments of Kaltenbrunner,[2] which were fully confirmed on repetition, the blood in inflammation was at first observed streaming to the irritated part, in consequence of which the capillary vessels became distended; afterwards irregularity of circulation occurred in the gorged capillary system; and subsequently complete arrest of the flow, and disorganization. These phenomena are of themselves sufficient to prove the existence of a separate action of the capillaries, and, taken in conjunction with other facts, are overwhelming. The blush of modesty, and the paleness of guilt, the hectic glow, and the translucency of congelation are circumstances that go to establish the same point.

The contractile power of the capillaries is doubtless modified by the condition of the nerves distributed to them, which, as we have seen, are observed to increase as the size of the vessels and the thickness of their coats diminish. Their influence is strikingly evinced in actions, that are altogether nervous, as in the flushed countenance occasioned by sudden mental emotion. By some, however, the whole capillary circulation has been ascribed to a motive faculty inherent in the corpuscles of the blood; whilst others, again, have asserted, that the "electro-galvanic power,"—or in other words—the nervous power, generated in the nervous system, and acting on the blood corpuscles through the parietes of the capillaries, is the immediate agent that directs the circulation in the capillaries. All this, however, enters into the inscrutable question,—what is the cause of life in the fluids or tissues,—a question to be agitated, but not solved, in a subsequent part of this volume.

But, not only has a vital power of contraction been conceded to the capillaries; it has been imagined, that they possess what the Germans call a Lebensturgor (*turgor vitalis*) or vital property of expansibility or turgescence. Such is the opinion of Hebenstreit[3] and of Prus;[4] and it has been embraced, in this country, by Professor Smith of Yale College; by his son, Professor N. R. Smith of Baltimore, in his excellent work on the "Arteries,"[5] and by Professor Hodge,[6] of

[1] Thomson's Lectures on Inflammation, Edinb., 1813.

[2] Experimenta circa Statum Sanguinis et Vasorum in Inflammatione, p. 23, Monach., 1826.

[3] Dissert. de Turgore Vitali, Lips., 1795; Hildebrandt's Physiologie, Auflag. 5, § 84; and Tiedemann's Physiologie, trad. par Jourdan, p. 625, Paris, 1831.

[4] De l'Irritation, &c., Paris, 1825.

[5] Surgical Anatomy of the Arteries, 2d edit., Baltimore, 1835.

[6] North Amer. Med. and Surg. Journal, June, 1828.

Philadelphia. The idea has been esteemed to be confirmed by the fact of excitants having been seen under the microscope, by Hastings, Wedemeyer, and others, to occasion not only contraction but dilatation of the capillaries. The phenomena observed in the erectile tissues have likewise been considered to favour the hypothesis; but in answer to these arguments it may be replied, that the irregular excitation, produced in the parts by the application of powerful stimulants, might readily give occasion to an appearance of expansibility under the microscope, without our being justified in inferring, that these vessels possess an innate vital property of expansibility; and, in many of the cases, in which ammonia and galvanism were applied by Thomson, Hastings, Wedemeyer, and others, the action of contraction ought rather to be esteemed physical or chemical than vital. The results of the application of such excitants, as diluted alcohol, dilute solutions of ammonia and chloride of sodium, can alone be adduced as evidences of vital action on the part of those vessels. The dilatation of the capillary system and of the smaller arteries, which has been remarked on the contact of those agents, is not, as Oesterreicher[1] has remarked, the primary effect: it is the consequence of the afflux of blood to the irritated part, as was demonstrated, also, in the experiments of Kaltenbrunner on inflammation, to which allusion has been made. Lastly, attentive observation of the phenomena presented by the erectile tissues must lead to the conclusion, that turgescence of vessels is not the first link in the chain of phenomena; excitation is first induced in the nerves of the part—generally through the influence of the brain, and thence, perhaps, through the sympathetic nerve,—and the afflux of fluid supervenes on this. The vital expansibility of the capillaries cannot, we think, be regarded as proved, or probable.

Professor Draper, of New York, maintains, that the great agency in the circulation of the blood is of a physical character; and is dependent upon the chemical relations of that fluid to the tissues with which it is brought in contact. On the principles of capillary attraction—he says —a liquid will readily flow through a porous body for which it has a chemical affinity; but it will refuse to flow through it, if it has no affinity for it. On this principle he explains why the arterial blood presses the venous before it in the systemic circulation, and why the reverse takes place in the pulmonic. "The systemic circulation takes place because arterial blood has a high affinity for the tissues, and venous blood little or none. The pulmonary circulation takes place because venous blood has a high affinity for atmospheric oxygen, which it finds on the air cells of the lungs; and arterial blood little or none. On the same principle we may explain the rise of sap in trees, the circulatory movements in the different animal tribes, and the minor circulations of the human system."[2] Dr. Dowler,[3] of New Orleans, whilst he earnestly combats the views of Professor Draper, is a strong

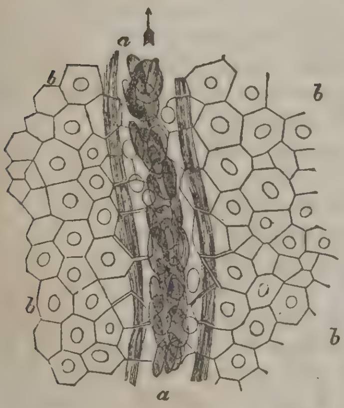
[1] Versuch einer Darstellung der Lehre vom Kreislauf des Blutes, Nürnberg, 1826.

[2] A Text-Book of Chemistry, p. 392, New York, 1846; and On the Forces which Produce the Organization of Plants, chap. iii.

[3] Researches, Critical and Experimental, on the Capillary Circulation. (Reprinted from the New Orleans Medical and Surgical Journal.) January, 1849.

advocate for the distinct action of the capillary vessels, and he adduces a number of striking experiments to establish his position. In perhaps one-fourth of the dissections which he records, the bodies were carried to the dissecting-room a few minutes after death. The external veins, chiefly those of the arms and neck, sometimes became distended; and when they were opened, the blood often flowed in a good stream, and was, at times, projected to the distance of a foot or more. In some cases, by putting a ligature around the arm, or by grasping it above the elbow, the blood was made to flow more freely, and by moving the muscles, as is done in ordinary bloodletting, the blood shot forth for some distance. Punctures in the middle of the subclavian discharged blood, which arose in a full stream, against gravity, two or three inches; sometimes forming an arch as it fell. The coronary veins discharged blood rapidly and "with surprising force." The dissections are considered by Dr. Dowler to show conclusively the independent action of the capillaries; "which in yellow fever, and other acute fevers, probably survives respiration and the heart's action; and when it ceases cadaveric hyperæmia takes place." Such is doubtless the fact; but it may still be questioned, whether anything more than the physical capillarity invoked by Professor Draper is concerned in the phenomenon. In a case observed by the author, and referred to elsewhere, blood flowed freely from the vessels of the brain, and coagulated fifteen hours after the cessation of respiration and circulation; and many similar cases are on record.

Fig. 299.



Small Venous Branch, from the Web of a Frog's Foot, magnified 350 diameters.

b, b. Cells of pavement epithelium, containing nuclei. In the space between the current of oval blood corpuscles, and the walls of the vessel, the round transparent lymph globules (?) are seen. (Wagner.)

The circulation through the capillaries has long been an interesting topic of microscopic research. According to Wagner,[1] a magnifying power of from two to three hundred diameters is required to make out the particular details. The blood in mass, or in the larger channels, he says, is seen to flow more rapidly than in the smaller. Here the blood corpuscles advance with great rapidity, especially in the arteries, and with a whirling motion, and form a closely crowded stream in the middle of the vessel, without ever touching its parietes. With a little attention, a narrower and clearer, but always very distinct space is seen to remain between the great middle current of blood corpuscles and the walls of the vessel, in which a few white corpuscles, or what Wagner considers to be lymph corpuscles, are moved onwards, but at a much slower rate. These white corpuscles swim in smaller numbers in the transparent liquor sanguinis,

[1] Elements of Physiology, translated by R. Willis, § 122, Lond., 1842.

and glide slowly, and in general smoothly, though they sometimes advance by fits and starts more rapidly, but with intervening pauses; and, as a general rule, at least ten or twelve times more slowly than the corpuscles of the central stream. The clear space, filled with liquor sanguinis and white corpuscles, is obvious in all the larger capillaries, whether arterial or venous, but ceases to be apparent in the smaller intermediate vessels which admit but one or two rows of blood corpuscles (Fig. 283). In these vessels, two sets of corpuscles proceed *pari passu;* but, according to Wagner, it is easy to see, that the blood corpuscles glide more readily onwards,—the white corpuscles seeming often to be detained at the bendings of vessels, and at the angles, where anastomosing branches are given off: here they remain adherent for an instant, and then suddenly proceed onwards. These phenomena are observed in every part of the peripheral systemic circulation; but an exception appears to exist in the pulmonic circulation; the capillaries there being filled with both kinds of corpuscles to their very walls.

Fig. 300.

Large Vein of Frog's Foot, magnified 600 diameters.

b, c. Blood corpuscles. *a, a.* Lymph corpuscles (?) principally conspicuous in the clear space near the parietes of the vessel. (Wagner.)

It is in this—the intermediate—part of the sanguiferous system, that most important functions take place. In the smallest artery we find arterial blood; and in the smallest vein communicating with it blood always possessing venous properties. Between those points, a change must have occurred, the reverse of that which happens in the lungs. It is here, too, that nutrition, secretion, and calorification are effected. In the explanation of these functions, we shall find it impossible not to suppose a distinct and elective agency in the tissues concerned; and as it is by such agency, that the varying activity of the different functions is regulated, we are constrained to believe, that the capillary vessels may be able to exert a controlling influence over the quantity and velocity of the blood circulating in them. In disease, the agency of this system of vessels is an object of attentive study with the pathologist. To its influence in inflammation we have already alluded; but it is no less exemplified in the more general diseases of the frame,—as in the cold, hot, and sweating stages of an intermittent. Local, irregular capillary action is, indeed, one of the most common causes or effects of acute diseases, and this generally occurs in some organ at a distance from the seat of the deranging influence. It is a common and just observation, that getting the feet wet, and sitting in a draught of air, are

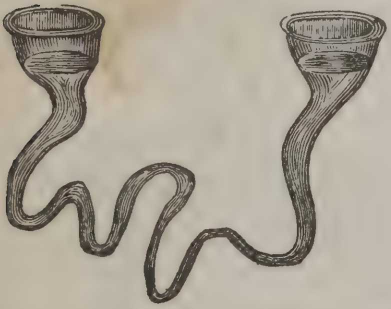
more certain causes of catarrh than sudden atmospheric vicissitudes, that apply to the whole body; and so extensive is the sympathy between the various portions of this system of vessels, that the most diversified effects are produced in different individuals exposed to the same common cause; one may have inflammatory sore throat; another, ordinary catarrh; another, inflammation of the bowels;—according to the precise predisposition, existing in the individual at the time, to have one structure morbidly affected rather than another;—but these are interesting topics, which belong more strictly to the pathologist.

By the united action, then, of the heart, arteries, and capillary or intermediate system of vessels, the blood attains the veins. We have now to consider the circulation in these vessels.

d. *Circulation in the Veins.*

It has been already observed, that Harvey considered the force of the heart to be of itself sufficient to return the blood, sent from the left ventricle, to the heart; whilst Bichat conceived the whole propulsory effort to be lost in the capillaries, and the transmission of the blood along the veins to be entirely effected by the agency of the capillary system. It is singular, that an individual of such distinguished powers of discrimination should have been led into an error of this magnitude. It is a well-known principle in hydrostatics, that although water, when unconfined, can never rise above its level at any point, and can never move upwards; yet, by being confined in pipes or close channels of any kind, it will rise to the height from which it came. Hence the water or blood in the vessel A, Fig. 301, which may be considered to represent the right auricle, would stand at the same height as that in the vessel B, which we may look upon as the left ventricle,—were they inanimate tubes. We need be at no loss, therefore, in understanding how the blood might attain the right auricle, when the body is erect, by this hydrostatic principle alone; but we have seen, that the force exerted by the heart, arteries, and capillary system is superadded to this, so that the blood would rise much higher than the right auricle, and consequently exert a manifest effort to enter it. It may be remarked, also, that the left ventricle is not the true height of the source, but the top of the arch of the aorta, which is more elevated by several inches than the right auricle. A similar view is embraced by Dr. Billing;[1] but Dr. Carpenter[2]—in commenting on the author's observations on this subject—suggests, that the influence of this hydrostatic

Fig. 301.



[1] First Principles of Medicine, Amer. edit., p. 36, Philad., 1842.
[2] Human Physiology, § 516, Lond., 1842.

force would scarcely be felt through the plexus of capillary vessels; "for the interposition of a system of tubes even of much larger calibre would be, by the friction created between the fluid and their walls, an effectual obstacle to the rapid ascent of a current, which had so slight an impetus as that derived from its previous fall." The author did not mean, however, to say more than that the blood "might attain" the right auricle by the hydrostatic force alone: he did not wish to convey the idea, that the circulation could be carried on without the aid of an additional force; but that a slight effort only on the part of the heart and arteries might be needed to enable the blood to perform its entire circuit. It is proper to add, that in the last editions of his valuable work, Dr. Carpenter has omitted those comments on the observations of the author.

Are we then to regard the veins as simple elastic tubes? This is the prevalent belief. Their elasticity is, however, much less than that of the arteries. Some physiologists have conceived them to possess contractile properties also. Such is the opinion of M. Broussais,[1] who founds it, in part, upon certain experiments by M. Sarlandière, already referred to, in which contraction and relaxation of the venæ cavæ of the frog were seen for many minutes after the heart was removed from the body. These pulsations of the venæ cavæ, and of the pulmonary veins in their natural state, have been seen by numerous observers—by Steno, Lower, Wepfer, Borrachius, Whytt, Haller, Lancisi, Müller, Marshall Hall, Flourens, J. J. Allison, and others.[2] The experiments of Dr. Allison, in reference to the venæ cavæ and pulmonary veins, appeared to him to prove;—that they pulsate near the heart in the four classes of the vertebrata;—that in dying animals they pulsate long after the auricle and ventricle have ceased;—that they also beat even in quadrupeds, for hours after they have been separated from the heart and from the body;—and that they can be stimulated to contract, either in or out of the body, by mechanical and galvanic agency, especially by the latter, after all motion has ceased for some time.

It has been deemed doubtful, whether the veins generally possess any contraction like that of the venæ cavæ and the pulmonary veins near the heart, for although irritated by galvanic and mechanical stimuli by Haller, Nysten, Müller, J. J. Allison, and others, no motion whatever could be detected in them. It has been before shown, however, that non-striated muscular fibres enter into their composition, and Gerber affirms, that the fibres of their middle coat bear a stronger resemblance to those of muscular tissue than do those of the corresponding coat of the arteries, which more resemble ordinary elastic fibres; but Dr. Carpenter[3] thinks it not improbable, that his observations were made on portions of the veins near the heart, which partake of its contractility.

In the experiments of Dr. Marshall Hall[4] on the circulation in the

[1] Traité de Physiol., &c., Drs. Bell's and La Roche's translat., p. 391, Philad., 1832.

[2] See the experiments of the last named gentleman, proving the existence of a venous pulse independent of the Heart and Nervous System, in Amer. Journal of the Medical Sciences, Feb., 1839, p. 306.

[3] Human Physiology, § 514, note, Lond., 1842.

[4] Essay on the Circulation, ch. i., Lond., 1831, and Philad., 1835.

web of the frog's foot, he was almost invariably able to detect, with a good microscope, a degree of pulsatory acceleration of the blood in the arteries at each contraction of the heart; and he is disposed to conclude, that the natural circulation is rapid, and entirely pulsatory in the minute arteries, and slow and equable in the capillary and venous systems. But whenever the circulation was in the slightest degree impeded, the pulsatory movement became very manifest at each systole of the heart, and it was seen in all the three systems—arterial, capillary, and venous. He observed, that in the arteries there was generally an alternate, more or less rapid flow of the corpuscles at each systole and diastole of the ventricle; and that in the capillaries and veins the blood was often completely arrested during the diastole, and again propelled by a pulsatory movement during the systole;—all which he esteems conclusive proof, that the power and influence of the heart extend through the arteries to the capillaries, and through these to the veins, even in the extreme parts of the body. The experiments of Valentin[1] would seem, however, to show, that but little of the force of the left ventricle remains to propel the blood in the veins. He found, that the pressure of the blood in the jugular vein of a dog, as estimated by the hæmadynamometer of Poiseuille, was not more than $\frac{1}{11}$th or $\frac{1}{12}$th of that in the carotid artery. In the upper part of the vena cava inferior, he could scarcely detect any pressure; almost the whole force of the heart having been apparently consumed during the passage of the blood through the capillaries:[2] still—as Messrs. Kirkes and Paget[3] suggest—slight as this remanent force might be, it would be enough to complete the circulation, inasmuch as although the spontaneous dilatation of the auricles and ventricles may not be forcible enough to assist the movement of blood in them, it is adapted to present no obstacle to the movement.

That the veins are possessed of elasticity is proved by the operation of bloodletting, in which a part of the jet, on puncturing the vein, is owing to the over-distended vessel returning upon itself; but that this property exists to a trifling extent only is shown by the varicose state of the vessels, which is so frequently seen in the lower extremities.

e. *Forces that propel the Blood.*

From the inquiry into the agency of the different circulatory organs in propelling the blood, it is manifest, that the action of the heart, the elasticity of the arteries, and a certain degree of contractile action in the smaller vessels more especially, a distinct action of the capillary vessels, and a slight elastic and perhaps contractile action on the part of the veins, may be esteemed the efficient motors. Of these, the action of the heart and capillaries, and the contraction of the arteries and veins, can alone be regarded as sources of motion, the elasticity of the vessels being simple directors, not generators of force. But there is another agency, which is probably more efficient than has been generally conceived. This is the *suction power* of the heart, or *derivation*

[1] Lehrbuch der Physiologie des Menschen, i. 477, Braunschweig, 1844.
[2] Magendie. Leçons sur les phénomènes physiques de la vie, iii. 152, Paris, 1837.
[3] Manual of Physiology, Amer. edit., p. 113, Philad., 1849.

as it has been termed, to which attention has been chiefly directed by Haller,[1] Wilson,[2] Carson,[3] Zugenbühler, Schubarth, Platner, Blumenbach,[4] and others; but which is not assented to by Oesterreicher,[5] Müller,[6] and some others.[7] It is presumed, that the muscular fibres of the heart are mixed up with a large quantity of areolar tissue; and that whilst the contraction of the cavities is effected by the action of the muscular fibres, dilatation is produced by the relaxation of the contracted fibres, and the elasticity of the areolar tissue; so that when the heart has contracted, and sent its blood onwards, its elasticity instantly restores it to its dilated condition; a vacuum is formed, and the blood rushes in to fill it. This action has been compared by Dr. Bostock,[8] and by Dr. Southwood Smith,[9] Prof. Turner,[10] and others, to that of an elastic gum bottle, which, when filled with water, and compressed by the hand, allows the fluid to be driven from its mouth with a velocity proportionate to the compressing force; but the instant the pressure is removed, elasticity begins to operate, and if the mouth of the bottle be now immersed in water, a considerable quantity of that fluid will be drawn up into the bottle, in consequence of the vacuum formed within it. The existence of this force is confirmed by Döllinger,[11]—who, when examining the embryos of birds, saw the blood advance along the veins, and the venous trunks pour it into the auricles at the moment they dilated to receive it: as well as by Dr. T. Robinson,[12] and M. Cruveilhier,[13] who were forcibly struck with the activity with which the diastole was effected, in the cases of monstrosity more than once referred to. Dr. Carpenter[14] thinks it very doubtful "how far the auricles have such a power of active dilatation as would be required for this purpose;" but the question need not regard the auricles. It is but necessary to suppose, that an action or power of dilatation exists in the ventricles; and this is now generally admitted. He farther remarks, that it has been shown experimentally by Dr. Arnott and others, that no suction power exerted at the farther end of a long tube, whose walls are as deficient in firmness as those of the veins are, can occasion any acceleration in a current of fluid transmitted through it; for the effect of the suction is destroyed at no great distance from the point at which it is applied by the flapping together of the sides of the vessel; but in answer to this it may be observed, that it remains to be shown, that

[1] Elem. Physiol., ii. lib. vi.
[2] Enquiry into the Moving Powers employed in the Circulation of the Blood., Lond., 1784.
[3] Inquiry into the Causes of the Motion of the Blood, 2d edit., Lond., 1833.
[4] Institutiones Physiologicæ, § 126, Gotting., 1798.
[5] Lehre vom Kreislauf des Blutes, Nürnberg, 1826.
[6] Handbuch, u. s. w., Baly's translation, p. 173.
[7] Burdach, Physiologie als Erfahrungswissenschaft, iv. 270, Leipz., 1832.
[8] Physiology, 3d edit., p. 251, Lond., 1836.
[9] Animal Physiology, (Library of Useful Knowledge,) p. 83, Lond., 1829.
[10] Edinb. Medico-Chirurg. Transact., iii. 225.
[11] Denkschriften der Königl. Akademie der Wissenschaft. zu München, vii. 217; and Burdach, op. citat., p. 272.
[12] American Journal of the Medical Sciences, No. xxii.
[13] Gazette Médicale de Paris, 7 Août, 1841, p. 535; cited in Brit. and Foreign Medical Review, Oct. 1841, p. 535.
[14] Human Physiology, § 515, Lond., 1842.

such flapping of the sides would necessarily occur in the veins, which are living vessels, and constantly receiving blood from the capillaries under the action of vital forces.

Another accessory force, that has been invoked, is the suction power of the chest or *inspiration of venous blood*, as it has been termed. This is conceived to be effected by the same mechanism as that which draws air into the chest. The chest is dilated during inspiration; an approach to a vacuum occurs in it; and the blood, as well as the air, is forcibly drawn towards that cavity. On the other hand, during expiration, all the thoracic viscera are compressed; the venous blood is repelled from the chest, and the arterial blood reaches its destination with greater celerity, owing to the action of the expiratory muscles being added to that of the left ventricle. Haller,[1] Lamure,[2] and Lorry,[3] had observed, that the blood in the external jugular vein moves under manifestly different influences during inspiration and expiration. Generally, when the chest is dilated in inspiration, the vein empties itself briskly; becomes flat, and its sides are occasionally accurately applied against each other;—but during expiration it rises, and becomes filled with blood;—effects, which are more evident, when the respiratory movements are extensive. The explanation of this phenomenon by Haller and Lorry is the one given above.

To discover whether the same thing happens to the venæ cavæ, M. Magendie introduced a gum elastic catheter into the jugular vein, so as to penetrate the vena cava and even the right auricle:—the blood was observed to flow from the extremity of the tube at the time of expiration only. During inspiration, air was rapidly drawn into the heart, giving rise to the symptoms to be mentioned hereafter, which attend the reception of air into that organ. Similar results were obtained, when the tube was introduced into the crural vein in the direction of the abdomen. So far as regards the larger venous trunks, therefore, the influence of respiration on the circulation is sufficiently evidenced.[4]

It can be easily shown, by opening an artery of the limbs, that expiration—especially forced expiration, and violent efforts—manifestly accelerate the motion of arterial blood. In animals subjected to experiment, it is impracticable to excite either the forced expiration or violent effort at pleasure; but we can, as a substitute, compress the sides of the chest with the hands, according to the plan recommended by Lamure; when the blood will be found to flow more or less copiously in proportion to the pressure exerted. It occurred to M. Magendie, that this effect of respiration on the course of the blood in the arteries might influence the flow along the veins. To prove this, he passed a ligature around one of the jugular veins of a dog. The vessel emptied itself beneath the ligature, and became turgid above it. He then made a slight puncture with the lancet in the distended portion; and in this way obtained a jet of blood, which was not sensibly modified by the ordinary respiratory movements, but became of triple or quadruple the size, when the animal struggled. As it might be objected to this experiment, that

[1] Elementa Physiologiæ, tom. ii. lib. vi. sect. iv. § 8, Lausann., 1760.
[2] Mém. de l'Acad. des Sciences, pour 1749.
[3] Magendie, Précis, &c., ii. 416.
[4] Poiseuille, in Magendie's Journal de Physiologie, viii. 272.

the effect of respiration was not transmitted by the arteries to the open vein, but rather by the veins that had remained free, which might have conveyed the blood repelled from the vena cava towards the tied vein by means of anastomoses, the experiment was varied. The dog has not, like man, large internal jugular veins, which receive the blood from the interior of the head. The circulation from the head and neck is, in it, almost wholly confined to the external jugular veins, which are extremely large; the internal jugulars being little more than *vestiges.* By tying both of these veins at once, M. Magendie made sure of obviating, in great part, the reflux in question; but, instead of this double ligature diminishing the phenomenon under consideration, the jet became more closely connected with the respiratory movement; for it was manifestly modified even by ordinary respiration, which was not the case when a single ligature was employed. From these and other experiments, he properly concluded that the turgescence of the veins must not be ascribed, with Haller, Lamure, and Lorry, simply to the reflux of the blood of the venæ cavæ into the branches opening directly or indirectly into them; but partly to the blood being sent in larger quantity into the veins from the arteries.[1] In the same manner are explained,—the rising and sinking of the brain, which, as was observed in an early part of this work, (vol. i. p. 108,) are synchronous with expiration and inspiration. During expiration, the thoracic and abdominal viscera are compressed: the blood is driven more into the branches of the ascending aorta, and is, at the same time, prevented from returning by the veins: owing to the combination of these causes, the brain is raised during expiration. In inspiration, all this pressure is removed; the blood is free to pass equally by the descending and ascending aorta; the return by the veins is ready, and the brain therefore sinks.[2] We can thus, also, explain why the face is red and swollen during crying, running, straining, and the violent emotions; and why pain is augmented in local inflammations of an extremity,—as in cases of whitlow; and when respiration is hurried or impeded by running, crying, &c. The blood accumulates in the part, owing to the compound effect of increased flow by the arteries, and impeded return by the veins. The same explanation applies to the production of hemorrhage by any violent exertion; and M. Bourdon[3] affirms, that he has always seen hemorrhage from the nose largely augmented during expiration; diminished at the time of inspiration; and arrested by prolonged inspiration; —a therapeutical fact of some interest.

Experiments with the hæmadynamometer by Poiseuille, and Ludwig,[4] confirm those mentioned above:—the column of mercury having been found to rise somewhat at each expiration, and to sink during inspiration.

It is manifest, then, that the circulation is modified by the move-

[1] Précis, &c., ii. 421.

[2] This motion of the brain must not be confounded with that which is synchronous with the contraction of the left ventricle; and is owing to the pulsation of the arteries at the base of the brain.

[3] Recherches sur la Méchanisme de la Respiration et sur la Circulation du Sang, Paris, 1820; see, also, Longet, Anatomie et Physiologie du Système Nerveux, pp. 777 and 779.

[4] Müller's Archiv. für Anatomie, u. s. w., Heft. iv. s. 242, Berlin, 1847.

ments of inspiration and expiration,[1]—the former facilitating the flow of blood to the heart by the veins, and the latter encouraging the flow by the arteries; and we shall see hereafter, that the dilatation of the chest,—which constitutes the first inspiration of the new-born child,—is the cause of the establishment of the new circulation; the same dilatation, which causes the entrance of air into the air-cells, soliciting the flow of blood, or the "inspiration of venous blood," as M. Magendie[2] has termed it. In a paper read before the Royal Society of London, in June, 1835, Dr. Wardrop,[3]—after remarking, that he considers inspiration as an auxiliary to the venous; and expiration to the arterial circulation,—attempts, on this principle, to explain the influence exerted on the circulation, and on the action of the heart, by various modes of respiration, whether voluntary or involuntary, under different circumstances. Laughing, crying, weeping, sobbing, and sighing, he regards as efforts made with a view to effect certain alterations in the quantity of blood in the lungs and heart, when the circulation has been disturbed by mental emotions. The influence of ordinary respiration can, however, be trifling; yet it has been brought forward by Sir David Barry[4] as the efficient cause of venous circulation. His reasons for this belief are,—the facts just mentioned, regarding the influence of inspiration on the flow of blood towards the heart; and certain ingeniously modified experiments, tending to the elucidation of the same result. He introduced one end of a spirally convoluted tube into the jugular vein of an animal,—the vein being tied above the point where the tube was inserted,—and plunged the other into a vessel filled with a coloured fluid. During inspiration, the fluid passed from the vessel into the vein: during expiration, it remained stationary in the tube, or was repelled into the vessel. Dr. Bostock[5] remarks, that he was present at some experiments, which were performed by Sir David at the Veterinary College in London, and it appeared sufficiently obvious, that when one end of a glass tube was inserted either into the large veins, into the cavity of the thorax, or into the pericardium,—the other end being plunged into a vessel of coloured water,—the water was seen to rise up the tube during inspiration, and descend during expiration. The conclusion of Sir David from these experiments is most comprehensive;—that "the circulation in the great veins depends upon atmospheric pressure in all animals possessing the power of contracting and dilating a cavity around that point, to which the centripetal current of their circulation is directed;" and he conceives, that as, during inspiration, a vacuum is formed around the heart, the equilibrium of pressure is destroyed, and the atmosphere acts upon the superficial veins, propelling their contents onwards to supply the vacuum; but independently of other objections, there are a few that appear convincing

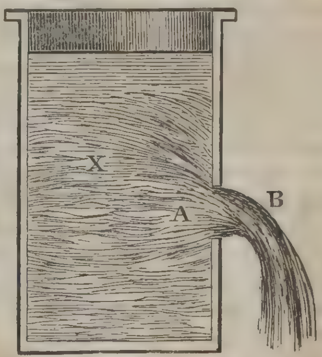
[1] Dr. Clendinning's Report to the Brit. Association, 1839-40, in Lond. Med. Gazette, Nov. 13, 1840, p. 270.
[2] Précis, &c., ii. 416.
[3] On the Nature and Treatment of the Diseases of the Heart; with some new views of the Physiology of the Circulation, Lond., 1837.
[4] Experimental Researches on the Influence of Atmospheric Pressure upon the Circulation of the Blood, &c., Lond., 1826.
[5] Physiology, 3d edit., p. 330, note, Lond., 1836.

against the sole agency of ordinary respiration in effecting venous circulation. According to Sir David's hypothesis, blood ought to arrive at the heart at the time of inspiration only; and as there are, on the average, seventy-two contractions of the heart for every eighteen inspirations; or four contractions, or—what is the same thing—four dilatations of the auricle for each respiration; one of these only ought to be concerned in the propulsion of blood, whilst the rest should be bloodless; yet we feel no difference in the strength of the four pulsations. It is clear, too, if we adopt Sir David's reasoning, that, of the four pulsations, two, and consequently two dilatations must occur during expiration, at which time the capacity of the chest is actually diminished: moreover, holding the breath ought to suspend the circulation; and the respiratory influence cannot be invoked to explain the circulation in the fœtus or in aquatic animals. At the most, therefore, respiration can only be regarded as a feeble auxiliary in the circulation. In favour of his opinion of the efficiency of atmospheric pressure in causing the return of the blood by the veins, Sir David adduces the fact,—already referred to, under the head of Absorption,—that the application of an exhausted vessel over a poisoned wound prevents the absorption of the poison; but this, as we have seen, appears to be a physical effect, which would apply equally to any view of the subject.

In all these cases, the elastic resilience of the lungs, by contributing to diminish the atmospheric pressure from the outer surface of the auricles, may, likewise, as suggested by Dr. Carson,[1] have some agency in soliciting the blood into these cavities; but the agency cannot be great. It has recently been suggested by Liebig,[2] that the fluids of the body, in consequence of the cutaneous and pulmonary transpiration, acquire a motion towards the skin and lungs; but it is not easy to see that this could have any important effect on the circulation.

There is another circumstance of a purely physical nature, which may exert some influence upon the flow of the blood along the veins; the expanded termination of the venæ cavæ in the right auricle. To explain this, it is necessary to premise a detail of a few hydraulic facts. If an aperture, A, Fig. 302, exist in a cistern X, the water will not issue at the aperture by a stream of uniform size; but, at a short distance from the reservoir, it will be contracted as at B, constituting what has been termed the *vena contracta*. Now, it has been found, that if a tube technically called an *adjutage* be attached to this

Fig. 302.



Vena Contracta.

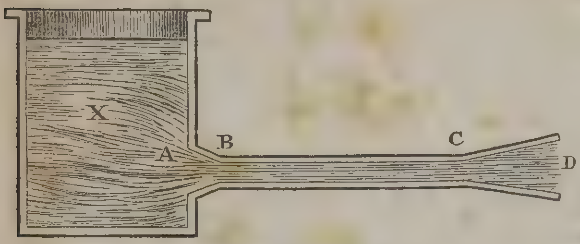
[1] Philosoph. Transact. for 1820, and An Inquiry into the Causes of Respiration, &c., 3d edit., Liverpool, 1833.

[2] Researches on the Motion of the Juices in the Animal Body, by W. Gregory, M.D., p. 74, London, 1848.

aperture, so as to accurately fit the stream, as at A B, Fig. 303, as much fluid will flow from the reservoir as if the aperture alone existed.

Again, if the pipe B C be attached to the adjutage A B, the expanded extremity at A will occasion the flow of water from the reservoir to be greater than it would be, if no such expanded extremity existed, in the ratio, according to Venturi, of 12·1 to 10; and if to the tube B C, a truncated conical tube C D be attached, the length of which is nearly nine times the diameter of C; and the diameter of C to that of D be as 1 to 8; the flow of water will be augmented in the proportion of 24 to 12·1; so that, by the two adjutages A B and C D, the expenditure through the pipe B C is increased in the ratio of 24 to 10. This fact,—the result of direct experiment, and so important to those who contract to supply water by means of pipes,—was known to the Romans. Private persons, according to Frontinus,[1] were in the habit of purchasing the right of delivering water in their houses from the public reservoirs, but the law prohibited them from making the conducting pipe larger than the opening allowed them in the reservoir, within the distance of fifty feet. The Roman legislature must, therefore, have been aware of the fact, that an adjutage with an expanded orifice, would increase the flow of water; but they were ignorant that the same effect would be induced beyond the fifty feet. A case—"The Schuylkill Navigation Company *against* Moore"—was tried in March term 1837, before the Supreme Court in Pennsylvania, in which these hydraulic principles were involved. The defendant had conveyed to him by the plaintiffs a certain lot of ground together with the privilege of drawing from the Schuylkill canal as much water as would pass through two metallic apertures of a size mentioned. He applied, however, to the aperture a conical tube or adjutage by which the flow of water was proved to have been greatly augmented. It was decided, that he had no right to increase the flow by such agency.[2]

Fig. 303.



Vena Contracta.

Let us apply this law of hydraulics to the circulation. In the first place, at the origin of the pulmonary artery and aorta, there is a manifest narrowness, formed by the ring at the base of the semilunar valves: this might be conceived unfavourable to the flow of the blood along those vessels during the systole of the ventricles; but from the law, which has been laid down, the narrowness would occupy the natural situation of the vena contracta, and, therefore, little or

[1] De Aquæductibus; Oudendorp, Lugd. Bat., 1731.

[2] Reports of Cases adjudged in the Supreme Court of Pennsylvania in the Eastern District. By Thomas I. Wharton, vol. ii. p. 477: Philadelphia, 1837.

no effect would be induced. The discharge would be the same as if no such narrowness existed. We have seen, again, that the vena cava becomes of larger calibre as it approaches the right auricle, and finally terminates in that cavity by an expanded aperture. This may have a similar effect with the expanded tube C D, Fig. 303, which doubles the expenditure.[1]

In making these conjectures,—some of which have been adduced by Sir Charles Bell,—it is proper to observe, that, in the opinion of some natural philosophers, the effect of the adjutage is entirely due to atmospheric pressure, and that no such acceleration occurs, provided the experiment be repeated *in vacuo*. Sir Charles Bell[2] conceives, that "the weight of the descending column in the reservoir being the force, and this operating as a *vis à tergo*, it is like the water propelled from the *jet d'eau*, and the gradual expansion of the tube permits the stream from behind to force itself between the filaments, and disperses them, without producing that pressure on the sides of the tube, which must take place, where it is of uniform calibre." It is on this latter view only, that these hydrostatic facts can be applied to the doctrine of the circulation.

In addition to the movements impressed on the blood by the parietes of the cavities in which it moves, it has been considered by many physiologists,—as by Harvey, Glisson, Bohn, Albinus, Rosa, Tiedemann, G. R. Treviranus,[3] Rogerson,[4] Alison,[5] and others,—to possess a power of automatic or self-motion. M. Broussais[6] asserts, that he has seen experiments,—originally performed by M. P. A. Fabre, which showed, that the blood, in the capillary system, frequently moves in an opposite direction to that given it by the heart,—repeated by M. Sarlandière on the mesentery of the frog. In these, the blood was seen to rush for some moments towards the point irritated; and, when a congestion had taken place there, they remarked, that the corpuscles took a different direction, and traversed vessels which conveyed them in an opposite course; and, a few seconds afterwards, they were again observed to return with equal rapidity to the point from which they had been repelled. Tiedemann[7] has collected the testimonies of various individuals on this point. Haller,[8] Spallanzani,[9] Wilson Philip,[10] G. R. Treviranus,[11] and others, have remarked, by the aid of the microscope, that the blood continued to move in the vessels of different animals, but chiefly of frogs, for some time after the great vessels had been tied, or the heart itself removed;—a fact which Tiedemann, also, often wit-

[1] Venturi, Sur la Communication Latérale du Mouvement dans les Fluides, Paris, 1798.
[2] Animal Mechanics, p. 40, in Library of Useful Knowledge, Lond., 1829.
[3] Tiedemann, Traité Complet de Physiologie de l'Homme, traduit par Jourdan, i. 348, Paris, 1831.
[4] A Treatise on Inflammation, &c., Lond., 1832.
[5] Edinburgh Med. and Surg. Journal for Jan., 1836.
[6] Traité de Physiologie, &c., translated by Drs. Bell and La Roche, 3d edit., p. 374, Philad., 1832.
[7] Op. citat. [8] Oper. Minor., i. 115, sect. 8.
[9] Exper. on the Circulation, &c., in Eng. by R. Hall, Lond., 1801.
[10] Philos. Transact., 1815; and Medico-Chirurg. Trans., vol. xii.
[11] Vermischte Schriften, i. 102.

nessed. C. F. Wolff,[1] Rolando,[2] Döllinger and Pander,[3] Prévost and Dumas,[4] Von Baer,[5] and others,[6] saw blood corpuscles in motion in the incubated egg, before the formation of either vessels or heart; and Hunter, Gruithuisen, and Kaltenbrunner observed,—in the midst of the areolar tissue of inflamed parts, in tissues undergoing regeneration, and during the cicatrization of wounds,—bloody points placed successively in contact with each other, forming small currents, which represented new vessels, and united to those already existing. The fact, indeed, that the embryo forms its own vessels, and that blood in motion can be detected before vessels are *in esse*, is a sufficient proof,—were there no other,—that the corpuscles of the blood possess the faculty of motion, either in themselves, or by virtue of an attraction exerted upon them by the solid parietes in which they move. Müller[7] thinks the idea of spontaneous motion in a fluid, independently of attraction or repulsion from the sides of another object, is inconceivable; and as Tiedemann[8] has remarked, if we admit this faculty in animals provided with a heart, the progression of the blood must be mainly owing to that viscus; for, after the heart ceases to act, the circulation is soon arrested. The blood, too, only remains fluid, and possesses the faculty of motion, whilst it is in connexion with the living body. When taken from the vessel in which it circulates, it soon coagulates, and loses its motive power. This motion has, by some,—and, according to Brandt,[9] not without grounds,—been presumed to be owing to electro-chemical agency.

Burdach[10] has properly observed, that the old but perfectly correct saying, "*ubi stimulus ibi affluxus*," means nothing more than that where the vital activity of an organ is augmented, more blood will be drawn to it; whence it naturally follows, that the progression of blood in the capillaries must be, in some measure, dependent on the activity of the vital manifestations in the tissue. It has been already shown, that if the capillary action be excited by stimulants, a greater flow of blood takes place into that system of vessels; and as the functions of nutrition and secretion are accomplished by that system, it is obvious, that any increase in the activity of those functions must attract a larger afflux of fluids, and, in this manner, modify the circulation independently of the heart and larger vessels. But this, again, can have but a subordinate influence on the general circulation.

Lastly, M. Raspail[11] resolves the whole of the circulation, as he does other functions, into a double action of *aspiration* and *expiration* by the tissues concerned. As the blood is the bearer of life to every

[1] Theoria Generationis, Hal., 1759.
[2] Dizionario Periodico di Medicina, Torino, 1822-1823.
[3] Dissert. sist. Hist. Metamorphoseos quam Ovum Incubatum prioribus quinque Diebus subit, Wirceb., 1817.
[4] Annales des Sciences Naturelles, tom. xii. p. 415, Dec., 1827.
[5] Ueber die Entwickelungsgeschichte der Thiere, u. s. w., Th. i. Königsberg, 1828.
[6] Allen Thomson, On the Formation of New Bloodvessels, Edinb., 1832; and art. Circulation, in Cyclopædia of Anat. and Physiology, p. 7, Lond., 1836.
[7] Handbuch, u. s. w., Baly's translation, p. 224, Lond., 1838.
[8] Op. cit., p. 349.
[9] Art. Blut, in Encyclopäd. Wörterb. der Medicinisch. Wissenschaft. v. 596, Berlin, 1830.
[10] Die Physiologie als Erfahrungswissenschaft, &c., Band. iv., Leipz., 1832.
[11] Chimie Organique, p. 364, Paris, 1833.

part of the organism, and of nourishment and reparation to the organs, —to prevent its destination being annulled, a part of the fluid, he says, must be absorbed by the surfaces, which it bathes: these surfaces must attract nutritive juices from the blood, and they must return to the blood the refuse of their elaboration,—in other words, they must *aspire* and *expire*. Now, this double function cannot take place without the fluid being set in motion, and this motion must be the more constant and uniform as the double function is inherent in every molecule of the surface of the vessels. In this way he accounts for the mercury, placed in a tube communicating with an artery, being kept at the same height near to, or at a distance from, the heart; because, he says, it is not the action of the heart which supports it, but the action of the parietes of the vessels. Every surface, which aspires, provided it is flexible, must be, in its turn, he conceives, attracted by the substance aspired, and, consequently, by the act of aspiration alone, the motions of systole and diastole of the heart and arteries may be explained. When their inner parietes aspire—or assimilate the fluid,—the heart will contract; when, on the contrary, they expire,—owing to the mutual repulsion between the heart and the fluid, the former dilates; and, as the movements of the heart are energetic on account of its size, its movements will add to the velocity of the circulation in the arteries, which will, therefore, besides their proper actions of aspiration and expiration, present movements isochronous with the pulsations of the heart. "Add to this accessory cause of arterial pulsations, the movements impressed by the aerial aspiration, which takes place in the lungs, and the circulation of the blood will no longer present insurmountable problems."

All this, it need scarcely be said, is ingenious; but nothing more.

f. *Accelerating and Retarding Forces.*

The above are the chief accelerating causes of the circulation. There are others, that at times accelerate, and at times retard; and others, again, that must always be regarded as impeding influences. All these are of a physical character, and applicable as well to inert hydraulic machines as to the pipes of the human body.

1. *Friction* always acts as a retarding force. That, which occurs between a solid and the surface on which it moves, can be subjected to calculation, but not so with a fluid, inasmuch as all its particles do not move equally: whilst one part is moving rapidly, another may be stationary, moving slowly, or even in a contrary direction, as is seen in rivers, where the middle of the stream always flows with greater velocity than the sides. The same thing happens to water flowing through pipes; the water, which is in contact with the sides of the pipe, moves more slowly than that at the centre. This retarding force is much diminished by the polished state of the inner surface of the bloodvessels, as is proved by the circumstance, that if we introduce an inert tube into an artery, the blood will not flow through it for any length of time. M. Poiseuille[1] infers, from his investigations, that a still layer of serum lines the interior of the capillary vessels, which may have some effect

[1] Biblioth. Universelle, Novemb., 1835.

in retarding the blood globules in their progress through the intermediate system. Yet the viscosity of the blood, within certain limits, would seem to be important to enable it to pass through the capillary system. M. Magendie, indeed, pronounces it to be an indispensable condition for its free circulation through the capillaries.[1]

2. *Gravity* may either be an active or retarding force, and is always exerting itself, in both ways, on different sets of vessels. If, for example, the flow of blood to the lower extremity by the arteries is aided in the erect attitude by the force of gravity, its return by the veins is retarded by the same cause. Every observer must have noticed, that the pulse of a person in health beats slower when he is in the recumbent, than in the erect, attitude. This is owing to there being no necessity for the heart to make use of unusual exertions for the purpose of forcing the blood, against gravity, towards the upper part of the body. In therapeutics, the physician finds great advantage from bearing this influence in mind; and, hence, in diseases of the head,—as in inflammation of the brain, in apoplectic tendency, ophthalmia, &c.,—he directs the patient's head to be kept raised; whilst in uterine affections the horizontal posture, or one in which the lower part of the body is raised even higher than the head, is inculcated; and in ulcers or inflammatory diseases of the lower extremities, the leg is recommended to be kept elevated. Every one, who has had the misfortune to suffer from whitlow, has experienced the essential difference in the degree of pain produced by position. If the finger be held down, gravity aids the flow of blood by the arteries, and retards its return by the veins: the consequence is turgescence and painful distension; but if it be held higher than the centre of the circulation, the flow by the arteries is impeded, whilst its return by the veins is accelerated, and hence the marked relief afforded.

3. *Curvatures.*—Besides friction, the existence of curvatures has considerable effect on the velocity and quantity of the fluid passing through pipes. A jet does not rise as high from the pipe or adjutage of a reservoir, if there be an angular turn in it, as if the bend were a gradual curve or sweep. The expense of force, produced by such curvatures in arteries, is seen at each contraction of the ventricle,—the tendency in the artery to become straight producing an evident movement, which has been called *locomotion of the artery*, and has been looked upon, by some, as the principal cause of the pulse. This motion is, of course, more perceptible the nearer to the heart, and the greater the vessel; hence it is more obvious at the arch of the aorta; and we can now understand why this arch should be so gradual. There is a striking example of the force used in this effort at straightening the artery, in the case of the popliteal artery, when the legs are crossed, and a curvature thus produced. The force is sufficient to raise a weight of upwards of fifty pounds at each contraction of the ventricle, notwithstanding it acts at the extremity of so long a lever. This fact is sufficient to exhibit the inaccuracy of the notion of MM. Bichat and Bricheteau,[2] that the curvatures in the arteries can have no effect in

[1] Lectures on the Blood, edit. cit., p. 102, Philad., 1839.

[2] Clinique Médicale, p. 145, Paris, 1835; or the author's translation in his American Medical Library, Philad., 1837.

retarding the flow of blood. Such could only be the case, Bichat thinks, if the vessels were empty at each systole.

3. *Anastomoses.*—The anastomoses of vessels have, doubtless, also some influence on the course of the blood; but it is impossible to appreciate it. The superficial veins are especially liable to have the circulation impeded by compression in the different postures of the body; but, by means of the numerous anastomoses if the blood cannot pass by one channel, it is diverted into others. Although, however, a forcible compression may arrest or retard the flow by those vessels, a slight degree of support prevents the vein from being dilated by the force of the blood passing into it, and thus favours its motion. The constant pressure of the skin hence facilitates the circulation through the subcutaneous veins, and if, by any means, the pressure be diminished, especially in those parts in which the blood has to make its way against gravity—as in the lower extremities—varices or dilatations of the vessels supervene, which are remedied by the mechanical compression of an appropriate bandage.

Attempts have been made to calculate the velocity with which the blood proceeds in its course; and how long it would take for a blood corpuscle, setting out from the left side of the heart, to attain the right side. It is clear, that the data are, in the first place, totally insufficient for any approximation. We know not the exact quantity of blood contained in the vessels;—the amount sent into the artery at each contraction of the ventricle; the relative velocity of the arterial, venous, and capillary circulations;—and, if we knew them at any one moment, they are liable to incessant fluctuations, which would preclude any accurate average from being deduced. Were these circumstances insufficient to exhibit the inanity of such researches, the varying estimates of different observers would establish it. These assign the time occupied in the circulation from two minutes to fifteen or twenty hours! Moreover, the distances which the corpuscles have to traverse must be various. In the heart, the passage from one side to the other by the coronary vessels is very short; whilst if the blood have to proceed to a remote part of the body, the distance is considerable.

Were we to regard the vascular system as forming a single tube;—by knowing the weight of the blood and the quantity which the left ventricle is capable of sending forward at each contraction, we could calculate with facility the period that must elapse before an amount equal to the whole mass is distributed. Thus, if we estimate, with many physiologists, the quantity propelled forward at each contraction of the ventricle to be two ounces; and the whole mass of blood to be 30 pounds, it will require, on an average, about 240 beats of the heart to send it onwards; which can be accomplished in little more than 3 minutes, yet, notwithstanding the absence of the requisite data, a modern writer has gone so far as to affirm the average velocity of the blood in the aorta to be about eight inches per second; whilst "the velocity in the extreme capillaries is found to be often less than one inch per minute"! A similar estimate was made by Dr. Young:[1] Hales,[2] too,

[1] An Introduction to Med. Literature, p. 609, Lond., 1813.
[2] Statical Essays, vol. ii. p. 40, Lond., 1733.

estimated the velocity of the blood, leaving the heart at 149·2 feet per minute, and the quantity of blood passing through the organ every hour at twenty times the weight of the blood in the body; but the judicious physiologist knows well, that in all operations, which are, in part, of a vital character, the results of every kind of calculation must be received with caution. In the larger animals, as the whale, the quantity of the fluid circulating in the aorta must be prodigious. Dr. Hunter, in his account of the dissection of a whale, states that the aorta was a foot in diameter, and that ten or fifteen gallons of blood were probably thrown out of the heart at each stroke; so that this vessel is, in the whale, actually larger than the main pipe of the old water-works at London Bridge; and the water, rushing through the pipe, it has been conceived, had less impetus and velocity than that gushing from the heart of this leviathan.[1]

But the highest of these estimates, as to the velocity of the circulatory current, is probably far beneath the truth, inasmuch as experiments have shown, that substances introduced into the venous circulation may be detected in the remotest parts of the arterial circulation in animals larger even than man in less than thirty seconds. Ten seconds after having injected a solution of nitrate of baryta into the jugular vein of a horse, Dr. Blake,[2] now of Saint Louis, drew blood from the carotid of the opposite side: after allowing this to flow for five seconds, he received the blood that flowed during the next five seconds into another vessel; and that which flowed after the twentieth second, by which time the action of the heart had stopped, was received into a third vessel. No trace of baryta could be detected in the blood that flowed between the tenth and fifteenth seconds; but it was discovered in that which flowed between the fifteenth and twentieth. In a dog, the poisonous effects of strychnia on the nervous system appeared in twelve seconds after injection into the jugular vein; in a fowl in six and a half seconds; and in a rabbit in four and a half seconds,—the interval being in an inverse ratio to the velocity of their respective circulations. From the results of these and other experiments, Dr. Carpenter thinks it difficult to resist the conclusion, that some other force than the contractions of the heart must have a share in producing the movement of the blood through the vessels.[3] If, however, we adopt the estimate of the average quantity of blood discharged by the left ventricle at each contraction, as given by Valentin,[4] a part of the difficulty is removed. He gives it at five ounces; so that thirty pounds of blood would require on an average, 96 contractions of the ventricle, which would be accomplished on an average in about a minute and a third. Mr. Paget says in from $43\frac{3}{4}$ to $62\frac{2}{3}$ seconds—the discordance being owing to the varying estimates as to the quantity of blood in the body. If we take the recent estimate of the amount of blood by Dr. Blake

[1] Paley's Natural Theology; and Animal Physiology, p. 75, Library of Useful Knowledge, Lond., 1829.

[2] Edinb. Med. and Surg. Journal, Oct., 1841; St. Louis Medical and Surgical Journal, Nov. and Dec., 1848; and American Journal of the Medical Sciences, p. 100, July, 1849.

[3] Human Physiology, § 491, Lond., 1842.

[4] Lehrbuch der Physiologie des Menschen, i. 415, Braunschweig, 1844.

(page 102), it could be accomplished in from 53 to 60 contractions of the ventricle, or in from 44 to 50 seconds. Valentin's estimate of the quantity sent out at each contraction is probably, however, too high: —three ounces may be nearer the mark.

With this velocity of the general circulation, it seems at first difficult to comprehend its slowness of progression in the capillary vessels, which in the frog, according to Valentin,[1] from many careful micrometric examinations, is from 0·938 to 1·4 English inch per minute. In the small veins, he says, it is about $\frac{1}{8}$th faster. These velocities, as Mr. Paget[2] remarks, agree nearly with those of Hales,[3] who estimated the velocity at an inch in a minute and a half; and more nearly still with those of Weber, who found it $1\frac{1}{4}$ inch per minute. On examining the circulation in the tongue of the frog, the blood is observed streaming with immense velocity through the larger vessels, whilst in those that admit but a single file of red corpuscles, the motion is as slow as described by those observers.

It has been well remarked by Messrs. Kirkes and Paget,[4] that the speed at which the blood may be seen moving in transparent parts is not opposed to the calculations of Valentin and others; inasmuch as, although the movement through certain capillaries may be very slow, the length of capillary through which any portion of blood has to pass is very small. "If we estimate that length at the tenth of an inch, and suppose the velocity of the blood therein to be only one inch per minute, then each portion of blood may traverse its own distance of the capillary system in about six seconds. There would thus be plenty of time left for the blood to travel through its circuit in the larger vessels, in which the greatest length of tube that it can have to traverse in the human subject does not exceed ten feet."

The velocity of the circulating fluid in the smaller vessels is generally thought to be less than in the larger; and their united calibres to be much greater than that of the trunk with which they communicate. Were this the case, the diminution of velocity would be in accordance with a law of hydrodynamics;—that when a liquid flows through a full pipe, the quantity which traverses the different sections of the pipe in a given time must be every where the same; so that where the pipe is wider the velocity diminishes: and, on the contrary, where it is narrower the velocity increases. This would not seem, however, to be consistent with the calculations of Dr. T. Young, and Weber, and the experiments of M. Poiseuille, already referred to, in which Drs. Spengler[5] and Valentin[6] concur, which show, that the pressure exerted on the blood in different parts of the body—as measured by the column of mercury, which the blood in different arteries will sustain—is almost exactly the same.

The cause of error in the common belief,—that the capacity of the arterial tubes increases in proportion to their distance from the heart,—has been explained by Mr. Ferneley[7] and others. It is true, he observes,

[1] Op. cit. [2] Loc. cit. [3] Op. citat., ii. 68.
[4] Manual of Physiology, Amer. edit., p. 118, Philad., 1849.
[5] Müller's Archiv., 1844, Heft i. [6] Op. cit., p. 456.
[7] London Medical Gazette, Dec. 7, 1839.

that the sum of the diameters of the branches is considerably greater than that of the trunk. Thus a trunk, 7 lines across, may divide into two branches of 5 lines each; or a trunk of 17 into three branches of 10, 10, and $9\frac{1}{2}$; but when their areas are compared, which is the only mode of arriving at their calibres, the correspondence is as close as can be reasonably expected, when the nature of the measurement is taken into account. In the first case, the area of the trunk is represented by the square of 7—that is 49; whilst the area of each branch will be 25, and the sum of the two will be 50. In the second instance, the area of the trunk will be 17 squared, or 289; whilst that of the branches is the sum of 100, 100, and $90\frac{1}{2}$, making $290\frac{1}{2}$. This will be more strikingly seen from the following table:—

	Trunks.		Branches.	
	Diameter.	Square of Diameter.	Diameter.	Sum of Squares of Diameter.
I.	9	81	7·5 + 5	81·25
II.	7·2	51·64	6 + 4	52
III.	3·5	12·25	3 + 2	13
IV.	7·0	49	5 + 5	50
V.	17	289	10 + 10 + 9·5	290·25
VI.	10	100	7 + 7 + 2	102
VII.	4·5	20·25	3·5 + 3	21·25
VIII.	8	64	4 + 7	65

It will be observed, that the sum of the squares of the diameters of the branches is in every case slightly more than the square of the diameter of the trunk. The discrepancy was found to be somewhat greater in subsequent experiments made by Mr. Paget.[1] The following table gives the ratio of the area of each arterial trunk to the joint area of its branches, as observed by him:—

	Trunk.		Branches.
Arch of the aorta	1	:	1·055
Innominata	1	:	1·147
Common carotid	1	:	1·013
External do.	1	:	1·19
Subclavian	1	:	1·055
Abdominal aorta to the last lumbar arteries	1	:	1·183
——— just before dividing	1	:	·893
Common iliac	1	:	·982
External iliac	1	:	1·15

Analogous experiments by actual admeasurement made by Mr. Erskine Hazard,[2] of Philadelphia, lead to a similar conclusion. It would appear, that where the aorta divides into the common iliacs, or at the division next lower down, the stream is always contracted; the effect of which must necessarily be to accelerate the circulation not only in the iliacs themselves, but in the arteries given off from the trunk above them,—as the mesenteric and the renal.

From what has been said regarding the curvatures and angles of vessels, it will be understood, that the blood must proceed to different organs with different velocities. The renal artery is extremely short, straight, and large, and must transmit the blood very differently to the

[1] London Medical Gazette, July 8, 1842.
[2] Horner, Special Anatomy and Histology, 7th edit., ii. 184, Philad., 1846.

kidney, from what the tortuous carotid does to the brain; or the spermatic artery to the testicle. A different impulse must, consequently, be made on the corresponding organs by these different vessels. A great portion, however, of the impulse of the heart must fail to reach the kidney, short as the renal artery is, owing to its passing off from the aorta at a right angle; and, hence, the impulse of the blood on that organ may not be as great as might be imagined at first.

The tortuosity of the carotid arteries is such as to greatly destroy the impetus of the blood; so that but trifling hemorrhage takes place when the brain is sliced away on a living animal, although it is presumed, that one-eighth of the whole quantity of blood is sent to the encephalon. Dr. Rush supposed, that the use of the thyroid body is to break the afflux of blood to the brain; for which its situation between the heart and head appeared to him to adapt it; and he adduced, as farther arguments,—*first*, the number of arteries it receives, although effecting no secretion; *secondly*, the effect on the brain, which he conceived to be caused by disease, and extirpation, of the thyroid; the operation having actually occasioned, in his opinion, in one case, inflammation of the brain, rapidly terminating fatally; and, *thirdly*, the fact that goïtre is often accompanied by idiotism. The opinion, however, is so entirely conjectural, and some of the *facts*, on which it rests, so questionable, that it does not demand serious examination.

This leads us to remark, that the thyroid body as well as other organs, with whose precise functions we are totally unacquainted,—as the thymus, spleen, and supra-renal capsules,—have been conceived to serve as diverticula or temporary reservoirs to the blood, when, owing to special circumstances, that fluid cannot circulate properly in other parts of the frame. M. Lieutaud having observed, that the spleen is always larger when the stomach is empty than when full, considered that the blood, when digestion is not going on, reflows into the spleen, and that thus this organ becomes a diverticulum to the stomach. The opinion has been indulged by many, with more or less modification. Dr. Rush's view was more comprehensive. He regarded the organ as a diverticulum, not simply to the stomach, but to the whole system, when the circulation is greatly excited, as in passion, or in violent muscular efforts, at which times there is danger of sanguineous congestion in different organs; and in support of this view, he invoked its spongy nature; the frequency of its distension; the large quantity of blood distributed to it; its vicinity to the centre of the circulation; and the sensation referred to it, in running, laughing, &c. M. Broussais[1] has still farther extended the notion of diverticula. He affirms, that they always exist in the vicinity of organs, whose functions are manifestly intermittent. In the fœtus, the blood does not circulate through the lungs as when respiration has been established: hence, diverticula are necessary: these are the thymus and thyroid glands. The kidneys do not act in utero; hence the use of the supra-renal capsules as diverticula. At birth, these organs are either wholly obliterated, if

[1] Commentaires des Propositions de Pathologie, &c., Paris, 1829; or, translation, p. 214, Philad., 1832.

the organs to which they previously served as diverticula have continuous functions; or they are partly obliterated, if the functions be intermittent. Thus, the spleen continues as a diverticulum to the stomach, because its functions are intermittent through life; and the thymus disappears when respiration is established: the liver and the portal system he regards as a reservoir for the reception of blood in cases of impediment to the circulation in different parts of the body.

These notions are entirely hypothetical. We shall see, hereafter, that our ignorance of the offices of the spleen, thymus, &c., is great; and we have already shown, that much more probable uses can be assigned to the portal system. The insufficiency of M. Broussais's doctrine of diverticula is strikingly evidenced by the fact, that whilst the thymus gland disappears gradually in the progress of age, the thyroid remains, as well as the supra-renal capsules.[1]

The nature of the circulation in the brain, as well as the advantages of the tortuous arrangement of the carotids, which convey a great portion of the blood to it, has been referred to before.[2] From the mode in which its vessels—arterial and venous—are distributed to it, a uniform supply of blood is secured; and it has been presumed, that this uniformity exists to such a degree, that no augmented quantity of blood can exist in it so as to exert undue pressure on the cerebral neurine. Resting chiefly on the recorded results of certain experiments by Dr. Kellie,[3] of Leith, many modern physiologists and therapeutists have maintained, that the quantity of blood in the cranium never varies; and that the brain is incompressible. Under this notion, Dr. Clutterbuck[4] affirmed, that no additional quantity of blood can be admitted into the vessels of the brain, the cavity of the skull being already filled by its contents. "A plethoric state or overfulness of the cerebral vessels altogether, though often talked of, can have no real existence; nor on the other hand can the quantity of blood within the vessels of the brain be diminished; no abstraction of blood, therefore, whether it be from the arm, or other part of the general system, or from the jugular veins (and still less from the temporal arteries) can have any effect on the bloodvessels of the brain, so as to lessen the absolute quantity of blood contained in them." Similar views were maintained by Monro Secundus,[5] and Dr. Abercrombie,[6] and they seemed to be supported by the experiments of Dr. Kellie, who inferred that, "in animals bled to death, whilst all the other organs of the body are nearly emptied of blood, the vessels of the brain contain the usual quantity; but that if, previous to bleeding an animal, a hole be made in its cranium, and the brain be thus exposed, equally with other organs, to atmospheric pressure, its vessels, like those of other parts of the body, will be emptied as the animal bleeds to death." It was important to establish the truth or inaccuracy of those views—influencing, as they were calculated to do,

[1] Adelon, Physiologie de l'Homme, tom. iii. 328, 2de édit., Paris, 1829.

[2] Vol. i. p. 107.

[3] Medico-Chirurgical Transactions of Edinburgh, i. 2.

[4] Art. Apoplexy, Cyclopædia of Practical Medicine, Amer. edit., by the author, Philad., 1844.

[5] Observations on the Structure and Functions of the Nervous System, Edinb., 1783.

[6] Pathological and Practical Researches on Diseases of the Brain and the Spinal Cord, Amer. edit., Philad.

and have done, in so essential a manner, the therapeutics of encephalic affections; and this has been conclusively accomplishd by Dr. Burrows.[1] The experiments of Dr. Kellie were repeated by him, but with *opposite* results; and he concludes, that it is not a fallacy, as some suppose, that bleeding diminishes the actual quantity of blood in the cerebral vessels; —that by it we not only diminish the momentum of the blood in the cerebral arteries and the quantity supplied to the brain in a given time, but actually diminished the amount of blood in these vessels. "Whether,"—he remarks—"the vacated place is replaced by serum or resiliency of the cerebral substance under diminished pressure, is a question into which I will not enter."

Dr. Burrows farther investigated, whether position can affect the quantity of blood in the vessels of the encephalon,—the opinion of Dr. Kellie from the results of his experiments having been in the negative. Two full grown rabbits were killed by hydrocyanic acid, and whilst their hearts still pulsated, one was suspended by the ears; the other by the hind legs. In this manner, they were left for twenty-four hours; and before they were taken down for examination, a tight ligature was placed around the throat of each, to prevent, as effectually as possible, any farther flow of blood to or from the head, after they were removed from their respective positions. The contrast in the appearance of the two animals was striking. The one presented a most complete state of anæmia of the internal as well as the external parts of the cranium; the other a most intense hyperæmia or congestion of the same parts; and these opposite conditions induced solely by posture, and the gravitation of the blood.

The *erectile tissues* offer a variety in the circulation, which requires some comment. Examples of these occur in the corpora cavernosa of the penis and clitoris; and in the nipple. They appear, according to Gerber,[2] to consist of a plexus or rete of varicose veins enclosed in a fibrous envelope, with relatively minute interspaces, which are occupied and traversed in all directions by arteries, nerves, contractile fibres, and by elastic, fibrous and areolar tissue. Of the particular arrangement of vessels in the corpora cavernosa, mention will be made hereafter: the mode of termination of the arteries in the erectile tissues has not been sufficiently studied, nor are views uniform in regard to their mode of action; some being of opinion, that they afford examples of vital expansibility; but as before remarked (page 161), excitation is first induced in the nerves of the part—generally through the influence of the brain—and the turgescence of vessels is a consequence.

The arrangement of the portal system of the liver is also peculiar, and has been given already (p. 99).

g. *The Pulse.*

We have had occasion, more than once, to refer to the subject of the pulse, or to the beat felt by the finger when applied over any of the larger arteries. Opinions have varied essentially regarding its cause.

[1] On Disorders of the Cerebral Circulation, Amer. edit., Philad., 1848.
[2] Elements of General Anatomy, by Gulliver, p. 298, Lond., 1842.

Whilst most physiologists have believed it to be owing to distension of the arteries, caused by each contraction of the left ventricle; some have admitted a systole and diastole of the vessel itself; others, as Bichat and Weitbrecht,[1] have thought that it is owing to the locomotion of the artery; others, that the impulse of the heart's contraction is transmitted through the fluid blood, as through a solid body; and others, as Dr. Young[2] and Dr. Parry,[3] that it is owing to the sudden rush forward of the blood in the artery without distension.

Bichat was one of the first, who was disposed to doubt, whether the dilatation of the artery, which was almost universally admitted, really existed; or if it did, whether it was sufficient to explain the phenomenon; and, since his time, numerous experiments have been made by Dr. Parry, the result of which satisfied him, that not the smallest dilatation can be detected in the larger arteries, when they are laid bare during life; nor does he believe, that there is such a degree of locomotion of the vessel as can account for the effect produced upon the finger. He ascribes the pulse to "impulse of distension from the systole of the left ventricle, given by the blood, as it passes through any part of an artery contracted within its natural diameter." Dr. Bostock[4] appears to coincide with Dr. Parry, if we understand him rightly, or at all. "According to this doctrine," he remarks, "we must regard the artery as an elastic and distensible tube, which is at all times filled, although with the contained fluid not in an equally condensed state, and that the effect produced upon the finger depends upon the amount of this condensation, or upon the pressure which it exercises upon the vessel, as determined by the degree in which it is capable of being compressed. Where there is no resistance to the flow of the blood along the arteries, there is no variation, it is conceived, in their diameter, and it is only the pressure of the finger or some other substance against the side of an artery that produces its pulse."

Most of the theories of the pulse take the contractility of the artery too little into account. In pathology, where we have an opportunity for observing the pulse in various phases, we meet with sensations, communicated to the finger, which it is difficult to explain upon any theory, except that of the compound action of the heart and arteries. The impulse is obviously that of the heart, and although the fact of distension escaped the observation of Bichat, Parry, Weitbrecht, Lamure, Döllinger, Rudolphi,[5] Jäger,[6] and others, we ought not to conclude, that it does not occur. It is, indeed, difficult for us to believe, that such an impulse can be communicated to a fluid filling an elastic vessel without pulsatory distension supervening. In opposition, too, to the negative observations of Bichat and Parry, we have the positive averment

[1] Comment. Acad. Imper. Scient. Petropol. ad An. 1734 and 1735, Petrop., 1740.

[2] Croonian Lectures, in Philos. Transact. for 1809, part i.

[3] An Experimental Inquiry into the Nature, Causes, and Varieties of the Arterial Pulse, by Caleb Hillier Parry, London, 1816; also, Additional Experiments on the Arteries of Warm-blooded Animals, &c., by Charles Henry Parry, M. D., &c., London, 1819.

[4] Physiology, 3d edit., p. 246, Lond., 1836.

[5] Grundriss der Physiologie, 2ter Band. 2te Abtheil., s. 301, Berlin, 1828.

[6] Tractatus Anatomico-physiologicus de Arteriarum Pulsu., Virceb., 1830.

of Dr. Hastings, and of Poiseuille,[1] Oesterreicher, Ségalas, and Wedemeyer, that the alternate contraction and dilatation of the larger arteries were clearly seen.[2]

The pulsations of the different arteries are pretty nearly synchronous with that of the left ventricle. Those of the vessels near the heart may be regarded as almost wholly so; but an appreciable interval exists in the pulsations of the more remote.

We have remarked, that the arterial system is manifestly more or less affected by the nerves distributed to it; that it may be stimulated by irritants, applied to the great nervous centres, or to the nerves passing to it; and this is, doubtless, the cause of many of the modifications of arterial tension, noticed in disease. Inflammation cannot affect a part of the system, for any length of time, without both heart and arteries participating, and affording unequivocal evidence of it. This, however, is a subject that belongs more especially to pathology.

The ordinary number of pulsations, per minute, in the healthy adult male, is from seventy to seventy-five; but this varies greatly according to temperament, habit of life, position,—whether lying, sitting, or standing, &c. Dr. Guy,[3] from numerous observations, found the pulse, in healthy males, of the mean age of 27 years, in a state of rest, 79 when standing; 70, sitting, and 67, lying; the difference between standing and sitting being 9 beats; between sitting and lying, 3 beats; and between standing and lying, 12 beats. When all exceptions to the general rule were excluded, the numbers were;—standing, 81; sitting, 71; lying, 66;—the difference between standing and sitting being 10 beats; between sitting and lying, 5 beats; and between standing and lying, 15 beats. The effect, produced upon the pulse by change of posture, Dr. Guy ascribes to muscular contraction, whether employed to change the position of the body, or to maintain it in the same position. In children, the difference between the pulse in the sitting and lying posture is often very marked. In a boy, six years of age, observed by the author, it amounted to fifteen beats; and Dr. Evanson[4] states, that he has often found the pulse—which at night (during sleep) was 80, full and steady—up to 100 or even 120 during the day, small and hurried,—and this in children six or seven years of age, and in perfect health.

In some individuals in health, the number of beats is singularly few. The pulse of a person known to the author was on the average thirty-six per minute; and Lizzari[5] affirms, that he knew a person in whom it was not more than ten. It is not improbable, however, that in these cases, obscure beats may have taken place intermediately, and yet not

[1] Repertoire générale d'Anatomie, &c., par Breschet, 1829, tom. vi. and vii, and Magendie's Journal de Physiol., viii. and ix.

[2] For a mode of estimating the arterial distension, see Poiseuille, in Magendie's Journal de Physiologie, ix. 44, and Jules Herison's description of an instrument—*Sphygmometer*—which makes the action of the arteries apparent to the eye.

[3] Guy's Hospital Reports, No. vi., April, 1838, p. 92.

[4] Practical Treatise on the Management and Diseases of Children, by Messrs. Evanson and Maunsell: Amer. edit., by Dr. Condie, p. 19, Philad., 1843.

[5] Raccolta D'Opusculi Scientifica, p. 265; and Good's Study of Medicine, Physiological Proem to class iii. Hæmatica. See Cases of Slowness of Pulse, by Mr. Mayo, Lond. Med. Gaz., May 5, 1838, p. 232.

have been detected. In a case of pericarditis, in which the author felt great interest, the pulse exhibited a decided intermission every few beats, yet the heart beat its due number of times; the intermission of the pulse at the wrist consisting in the loss of one of the beats of the heart. It was not improbable but that in this case the contractility of the aorta was unusually developed by the inflammatory condition of the heart; and that the flow of blood from the ventricle was thus occasionally spasmodically diminished or entirely impeded. The quickest pulse, which Dr. Elliotson[1] ever felt, was 208, counted easily, he says, at the heart; though not at the wrist.

The pulse of the adult female is usually from ten to fourteen beats in a minute quicker than that of the male. In infancy, it is generally irregular, intermitting, and always rapid, and it gradually becomes slower in the progress of age. It is, of course, impossible to arrive at any accurate estimate of its comparative frequency at different periods of life, but the average of the following numbers, on the authority of Heberden,[2] Sömmering, and Müller,[3] may, on the whole, be regarded as approximations.

Ages.	Number of beats per minute, according to		
	Heberden.	Sömmering.	Müller.
In the embryo, - - - - -	—	—	150
At birth, - - - - -	130 to 140	Do.	Do.
One month, - - - -	120	—	—
One year, - - - - -	120 to 108	120	115 to 130
Two years, - - - - -	108 to 90	110	100 to 115
Three years, - - - -	90 to 80	90	90 to 100
Seven years, - - - -	72	—	85 to 90
Twelve years, - - - -	70	—	—
Puberty, - - - - -	—	80	80 to 85
Adult, - - - - -	—	70	70 to 75
Old age, - - - - -	—	60	50 to 65

Dr. Guy[4] lays down the following as a near approximation to the average numbers at the several leading periods of life. It must be borne in mind, that, as in all similar cases, such averages can never apply to special examples.

At birth, - - - - -	140	Adult age, - - - - -	75
In infancy, - - - - -	120	Old age, - - - - -	70
Childhood, - - - - -	100	Decrepitude, - - -	75—80
Youth, - - - - - -	90		

Researches by MM. Hourmann and Dechambre,[5] do not accord with these estimates in respect to the smaller number of pulsations in the aged. MM. Leuret and Mitivié had suspected an error in this matter from an examination of 71 of the aged inmates of the Bicêtre and La Salpêtrière. MM. Hourmann and Dechambre examined 255 women

[1] Human Physiology, p. 215, London, 1840. [2] Med. Transact., ii. 21.
[3] Handbuch der Physiologie, Baly's translation, p. 171, London, 1838.
[4] Art. Pulse, Cyclop. of Anat. and Physiol., Pt. xxxi. p. 183, Lond., May, 1848.
[5] Archiv. Générales de Méd. pour 1835.

between the ages of 60 and 96, and found the average number of the pulse to be 82·29. M. Rochoux,[1] however, still believes—from the results of his own observations as well as those of others—that, as a general rule, the frequency of the pulse diminishes in the progress of age. The attention of Dr. Pennock,[2] of Philadelphia, has more recently been directed to the subject; and the author has great confidence in the authenticity of results recorded by him. In 170 males, and 203 females, of the average age of about 67, the average frequency of the pulse was 75. The difference between the pulse of the male and female continues to be well marked in advanced life. MM. Leuret and Mitivié found the average frequency in 27 aged men, 73; and in 34 aged women, 79. The average obtained by Dr. Pennock was 72 for the former; 78 for the latter.

Dr. Gorham[3] assigns 130 as the mean number of the pulse from five months to two years old; and 107·63 from two to four years of age, whence the number continues almost the same up to the tenth year. His estimates, however, are much higher than those of M. Valleix.[4] M. Trousseau,[5] from repeated observations, infers, that but little stress ought to be laid on the pulse in the diagnosis of disease in infants. He found, that during the first two weeks, it may vary from 78 to 150; during the second fortnight, from 120 to 164; from one to two months, from 96 to 132; two to six months, 100 to 162; six to twelve months, 100 to 160; and from twelve to twenty-one months, 96 to 140. From the observations of MM. Billard, Valleix, and others, it would seem, that the pulse of the fœtus at the moment it is expelled from the uterus often falls to 83 in the minute, and, in some minutes afterwards, rises to 160. In the course of the first day, it falls again to 127, and continues to diminish during the first ten days, the average being then from 87 to 90. These are, however, only averages: the variations are very great. Sex appeared to have some influence. In infants, from eight days to six months old, the average number of pulsations for boys was 131; for girls, 134; from six to twenty-one months, the average for boys was 113; for girls, 126. The state of sleeping or waking had a greater influence. In infants from fifteen days to six months old, the average of the pulse was 140 during waking; 121 during sleep. He has known it rise from 112 to 160 and 180, when the child cried or struggled. On the whole, M. Trousseau concludes, that the pulse of children at the breast varies from 100 to 150. After the first two months, it is a little more frequent in females than in males; and is about 20 higher in the waking than in the sleeping state.

Strange to say, it may be wholly absent, without the health seeming to be interfered with. A case of the kind is referred to by Prof. S. Jackson,[6] as having occurred in the mother of a physician of Philadel-

[1] Art. Pulse, in Dict. de Méd., 2d edit., xxv. 619, Paris, 1842.
[2] Amer. Journ. of the Medical Sciences, July, 1847, p. 68.
[3] Lond. Med. Gaz., Nov. 25, 1837.
[4] Mémoires de la Société Médicale d'Observation de Paris, tom. ii., Paris, 1844.
[5] Journ. des Connaiss. Méd. Chir., Juillet & Août, 1841; cited in Amer. Journ. Med. Sciences, Oct., 1841, p. 458, and Jan., 1842, p. 199.
[6] The Principles of Medicine, founded on the Structure and Functions of the Animal Organism, p. 492, Philad., 1832. A case of complete disappearance of the beating of the heart

phia. The pulse disappeared during an attack of acute rheumatism, and could never again be observed. Yet she was active in body and mind, and possessed unusual health. In no part of the body could a pulse be detected. Dr. Jackson attended her during a part of her last illness—inflammation of the intestines; no pulse existed. She died whilst he was absent from the city, and no examination of the body was made.

Between the number of pulsations and respirations there would not appear to be any fixed relation. In many persons the ratio in health is 4 to 1,[1] but in disease it varies greatly. Dr. Elliotson[2] alludes to a case of nervous disease in a female at the time in no danger whose respiration was 106, and pulse 104.

Dr. Knox[3] has made some observations on the pulsations of the heart, and on its diurnal revolution and excitability, from which he infers: 1. The velocity of the heart's action is in a direct ratio with the age of the individual,—being quickest in young persons, slowest in the aged. There may be exceptions to this, but they do not affect the general law. 2. There are no data to determine the question of an average pulse for all ages. 3. There is a morning acceleration and an evening retardation in the number of the pulsations independently of any stimulation by food, &c. 4. The excitability of the heart undergoes a daily revolution;—that is, food and exercise affect its action most in the morning and during the forenoon; less in the afternoon, and least of all in the evening. Hence it might be inferred, that the pernicious use of spirituous liquors must be greatly aggravated in those who drink before dinner. 5. Sleep does not farther affect the heart's action than through the cessation of all voluntary motion, and a recumbent position. 6. In weak persons, muscular action excites that of the heart more powerfully than in the strong and healthy; but this does not apply to other stimulants,—wine and spirituous liquors, for example. 7. The effect of the position of the body in increasing or diminishing the number of pulsations is solely attributable to the muscular exertion required to maintain the body in the sitting or erect posture; the debility may be measured by altering the position of the person from a recumbent to a sitting or erect one. 8. The most powerful stimulant to the heart's action is muscular exertion. The febrile pulse never equals this.[4]

h. *Uses of the Circulation.*

The chief uses of the circulation are,—to transmit to the lungs the products of absorption, in order that they may be converted into arterial blood; and to convey to the different organs arterial blood, which

is in Gazette Médicale, Nov. 21, 1836; and analogous cases are given in Parry on the Pulse, Bath, 1816, and in Medico-Chirurg. Review, xix. 285, and April, 1836.

[1] Quetelet, Sur L'Homme, p. 87; also, Guy, Pennock, &c., in Art. Pulse, op. cit., and Dr. John Reid, art. Respiration, ibid., pt. xxxii. p. 338, Lond., 1848.

[2] Human Physiology, p. 215, Lond., 1835. See, also, Dr. Ch. Hooker, of New Haven, Conn., in Boston Medical and Surgical Journal, for May 16, 23, &c., 1838.

[3] Edinburgh Medical and Surgical Journal, April, 1837.

[4] The article on the Pulse, by Dr. Guy, in Cyclop. of Anat. and Physiology, is an excellent *resumé* of the whole subject.

is not only necessary for their vitality, but is the fluid by which the different processes of nutrition, calorification, and secretion are effected. These functions will engage us next. We may remark, in conclusion, that the agency of the blood, as the cause of health or disease, has had greater importance assigned to it than it merits; and that although the blood may be the medium, by which the source of disease is conveyed to other organs, we cannot look to it as the seat of those taints that are commonly referred to it. "Upon the whole," says Dr. Good,[1] "we cannot but regard the blood as, in many respects, the most important fluid of the animal machine; from it all the solids are derived and nourished, and all the other fluids are secreted; and it is hence the basis or common pabulum of every part. And as it is the source of general health, so is it also of general disease. In inflammation, it takes a considerable share, and evinces a peculiar appearance. The miasms of fevers and exanthems are harmless to every part of the system, and only become mischievous when they reach the blood; and emetic tartar, when introduced into the jugular vein, will vomit in one or two minutes, although it might require perhaps half an hour if thrown into the stomach, and in fact it does not vomit till it has reached the circulation. And the same is true of opium, jalap, and most of the poisons, animal, mineral, and vegetable. If imperfectly elaborated, or with a disproportion of some of its constituent principles to the rest, the whole system partakes of the evil, and a dysthesis or morbid habit is the certain consequence; whence tabes, atrophy, scurvy, and various species of gangrene. And if it becomes once impregnated with a peculiar taint, it is wonderful to remark the tenacity with which it retains it, though often in a state of dormancy and inactivity for years, or even entire generations. For as every germ and fibre of every other part is formed and regenerated from the blood, there is no other part of the system that we can so well look to as the seat of such taints, or the predisposing cause of the disorders I am now alluding to; often corporeal, as gout, struma, phthisis: sometimes mental, as madness; and occasionally both, as cretinism."

This picture is largely overdrawn. Setting aside the erroneous pathological notions that assign to the blood what properly belongs to cell life in the system of nutrition, how can we suppose a taint to continue for years, or even entire generations, in a fluid which is perpetually undergoing mutation; and, at any distant interval, cannot be presumed to have one of its quondam particles remaining? Were all hereditary diseases derived from the mother, we could better comprehend this doctrine of taints; inasmuch as, during the whole of fœtal existence, she transmits the pabulum for the support of her offspring: the child is, however, equally liable to receive the taint from the father, who supplies no pabulum, but merely a secretion from the blood at a fecundating copulation, and from that moment can exert no influence on the character of the progeny. The impulse to this or that organization or conformation must be given from the moment of union of the particles, furnished by each parent at a fecundating intercourse; and

[1] Op. cit.

it is probable, that no material influence is exerted subsequently even by the mother, except through the pabulum she furnishes. The embryo accomplishes its own construction, as independently of the parents as the chick *in ovo*.

i. *Transfusion and Infusion.*

The operation of Transfusion,—as well as of Infusion of medicinal agents,—was referred to in an early part of this chapter, to prove the course of the circulation to be from the arteries into the veins. Both these operations were suggested by the discovery of Harvey. The former, more especially, was looked upon as a means of curing all diseases, and of renovating the aged *ad libitum*. The cause of every disease and decay was presumed to reside in the blood, and, consequently, all that was necessary was to remove the faulty fluid, and substitute pure blood obtained from a healthy animal in its place.

As a therapeutical agency, the history of this operation does not belong to physiology. The detail of the fluctuation of opinions regarding it, and its total disuse, are given at some length in the Histories of Medicine, to which we must refer the reader.[1] It appears to have been first performed on man in France by Denis and Emmerez in 1666; and in the following year it was practised in England by Drs. Lower and King.[2] Before this, however, many experiments had been made on animals. In his "Diary" under the date of the 14th of November, 1666, Pepys[3] has the following entry:—"Dr. Croone told me, that at the meeting of Gresham College to-night, which, it seems, they now have every Wednesday again, there was a pretty experiment of the blood of one dog let out, till he died, into the body of another on one side, while all his own run out on the other side. The first died upon the place, and the other very well, and likely to do well. This did give occasion to many pretty wishes, as of the blood of a Quaker to be let into an Archbishop, and such like; but, as Dr. Croone says, may, if it takes, be of mighty use to man's health, for the amending of bad blood by borrowing from a better body."

There are some interesting physiological facts, connected with transfusion, that cannot be passed over. MM. Prévost and Dumas found that the vivifying power of the blood does not reside so much in the serum as in the red particles. An animal bled to syncope was not revived by the injection of water or of pure serum at a proper temperature; but if blood of one of the same species was used, the animal seemed to acquire fresh life, at every stroke of the piston, and was at length restored.

The operation was revived by Dr. Blundell,[4] and by MM. Prévost and Dumas;[5] the first of whom employed it with safety, and he thinks with happy effects, in exhausting uterine hemorrhage. All these gen-

[1] Sprengel, K., Histoire de Médecine, par Jourdan, iv. 120, Paris, 1815.

[2] J. P. Kay, art. Transfusion, Cyclopædia of Practical Medicine, Amer. edit., by the author, iv., 468, Philad., 1845; and The Physiology, &c. of Asphyxia, p. 254, Lond., 1834.

[3] Diary and Correspondence of Samuel Pepys, F. R. S., by Lord Braybrooke, 3d edit., iii. 336, London, 1848.

[4] Médico-Chirurgical Transactions, ix. 56; and x. 296; and Researches physiological and pathological, p. 63, London, 1825.

[5] Bibliothèque Universelle, xvii. 215.

tlemen remark, that it can only be adopted with perfect safety in animals of like kinds, or in those the corpuscles of whose blood are of similar configuration. MM. Prévost and Dumas, Dieffenbach,[1] and Bischoff,[2] all agree as to the deadly influence of the blood of the mammalia when injected into the veins of birds. This influence, according to Müller, is in some way connected with the fibrin of the blood, and experiments have certainly shown, that blood deprived of fibrin acts most injuriously when injected into the vessels.[3]

The introduction of the practice of *infusing* medicinal agents into the blood was coëval with that of transfusion. It appears to have been first subjected to a philosophical examination by Sir Christopher Wren, who practised it on a malefactor in 1656.[4]

It is a singular fact, that in cases of infusion, medicinal substances are found to exert their specific actions upon certain parts of the body, precisely in the same manner as if they had been received into the stomach. Tartar emetic, for example, vomits, and castor oil purges, not only as certainly, but with much greater speed; for, whilst the former, as before remarked, requires to be in the stomach for fifteen or twenty minutes, before vomiting is excited, it produces its effect in one or two minutes, when thrown into the veins. Dr. E. Hale, of Boston, has published an interesting pamphlet on this subject.[5] In it he traces the history of the operation, detailing several interesting experiments upon animals; and one upon himself, which consisted in the introduction of a quantity of castor oil into the veins. In this experiment, he did not feel much inconvenience immediately after the injection; but very speedily experienced an oily taste, which continued for a length of time, and the medicine occasioned much gastric and intestinal disturbance, but did not act as a cathartic. Considerable difficulty was experienced in the introduction of the oil, to which circumstance M. Magendie[6] ascribes Dr. Hale's safety; for it is found, by experiments on animals, that viscid fluids, such as oil, are unable to pass through the pulmonary capillaries, in consequence of which the circulation is arrested, and death follows. Such, also, appears to have been the result of the experiments of Dr. Hale with powdered substances.

The injection of medicines into the veins has been largely practised at the Veterinary School of Copenhagen, and with complete success—the action of the medicine being incomparably more speedy, and the dose required much less. It is rarely employed by the physician, except in experiments on animals; but it is obvious, that it might be had recourse to with happy effects, where narcotic and other poisons have been taken, and where the mechanical means for their removal are not at hand.

[1] Die Transfusion des Blutes, Berlin, 1828.

[2] Müller's Archiv., 1835; cited in Baly's translation of J. Müller's Handbuch, u. s. w.

[3] See, on the different effects of transfusion of arterial and venous blood on animals, Bischoff, in Müller's Archiv., Heft iv. 1838, cited in Brit. and For. Med. Rev., April, 1839. p. 548.

[4] Chelius, System of Surgery, translated by South, Amer. edit., iii. 626, Philad., 1847.

[5] Boylston Medical Prize Dissertations, for the years 1819 and 1821, p. 100, Boston, 1821.

[6] Précis, &c., ii. 430.

4. CIRCULATORY APPARATUS IN ANIMALS.

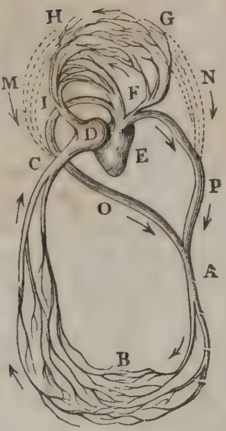
In concluding this subject, a brief allusion to the circulatory apparatus of other parts of the animal kingdom may be interesting and instructive.

In the *mammalia* in general, the inner structure of the heart is the same as in man; but its situation differs materially; and in some of them, as in the stag and pig, two small flat bones, called *bones of the heart*, exist, where the aorta arises from the left ventricle. In the amphibious mammalia and the cetacea, it has been supposed, that the foramen ovale in the septum between the auricles is open as in the human fœtus, to allow them to pass a considerable time under water without breathing; but the observations of Blumenbach, Cuvier, and others seem to show, that it is almost always closed. Sir Everard Home found it open in the sea otter, in two instances; but these are regarded by naturalists as exceptions to the general rule. In several of the web-footed mammalia and cetacea, as in the common otter, sea otter, and dolphin, particular vessels are always greatly enlarged and tortuous;—a structure which has been chiefly noticed in the vena cava inferior, and is supposed to serve the purpose of a diverticulum, whilst the animal is under water; or to receive a part of the returning blood, and retain it until respiration can be resumed.

In *birds*, the structure of the heart universally possesses a singular peculiarity. Instead of the right ventricle having a membranous valve, as in the left, and as in all the mammalia, it is provided with a strong, tense, and nearly triangular muscle, which aids in the propulsion of the blood from the right side of the heart into the lungs. This is presumed to be necessary, in consequence of their lungs not admitting of expansion like those of the mammalia, and of their being connected with numerous air-cells.

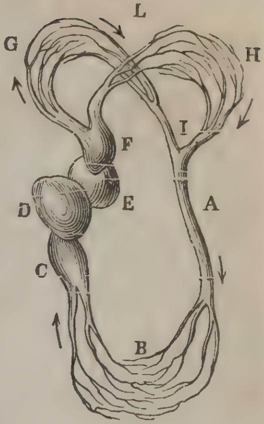
The heart of *reptiles* or *amphibia* in general consists either of only one ventricle, or of two, which freely communicate, so as to constitute essentially but one. The number of auricles always corresponds with that of the ventricles. That the cavities—auricular and ventricular—are, however, single, although apparently double, is confirmed by the fact, that, in all, there is only a single artery proceeding from the heart, which serves both for the pulmonic and systemic circulations. After this vessel has left the heart, it divides into two branches, by one of which a part only of the blood is conveyed to the lungs, whilst the other proceeds to different parts of the body. These two portions are united in the heart, and after being mixed together are sent again through the great artery. In these animals, therefore, aeration is less extensive than in the higher; and we can thus understand many of their peculiarities;—how, for example, the circulation may continue, when the animal is so situate as to be incapable, for a time, of respiration; as well as the great resistance to ordinary deranging influences, by which they are characterized. Fig. 304 represents the circulatory apparatus of the *frog;* in which E is the ventricle and D the auricle. From the former arises the aorta F, which soon divides into two trunks. These, after sending branches to the head and neck, turn

Fig. 304.



Circulation in the Frog.

Fig. 305.

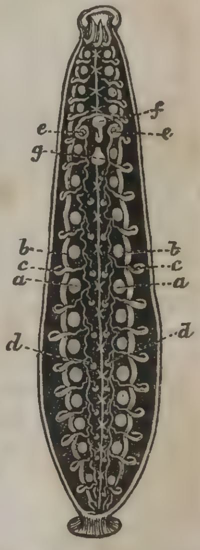


Circulation in Fishes.

downwards, (O and P,) and unite in the single trunk A. This vessel sends arteries to the body and limbs, which ultimately terminate in veins, and unite to form the vena cava C. From each of the trunks into which the aorta bifurcates at its origin arise the arteries F. These are distributed to the lungs, and communicate with the pulmonary veins, which return the blood to the auricle, D, where it becomes mixed with the blood of the systemic circulation. In the *tadpole* state, the circulation is branchial, as in fishes. The heart then sends the whole of its blood to the *branchiæ* or gills, and it is returned by veins following the course of the dotted lines M and N, (Fig. 304,) which unite to form the descending aorta. As the lungs undergo their developement, small arterial branches arise from the aorta and are distributed to those organs; and in proportion as these arteries enlarge, the original branchial arteries diminish, until ultimately they are obliterated, and the blood flows wholly through the enlarged lateral trunks, O and P, which, by their union, form the descending aorta.

In *fishes*, the heart is extremely small, in proportion to the body; and its structure is simple; consisting of a single auricle and ventricle D and E (Fig. 305). From the ventricle E an arterial trunk arises, which, in most fishes, is expanded into a kind of bulb, F, as it leaves the heart, and proceeds straight forward to the *branchiæ* or *gills*, G and H. From these, the blood passes into a large artery, A, analogous to the aorta, which proceeds along the spine, and conveys the blood to the various parts of the system; and, by the vena cava, C, the blood is returned to the auricle. This is, consequently, a case of single circulation.

Fig. 306.



Interior of the Leech.

a, a. Respiratory cells. *b, b.* Two large arteries. *c, c.* Mucous glands. *d, d.* Glands connected with the testicles. *e, e.* Testicles. *f.* Penis. *g.* Uterus. (Sir E. Home.)

Insects appear to be devoid of bloodvessels. Cuvier examined all the organs in them, which, in red-blooded animals, are most vascular, without discovering the least appearance of a bloodvessel, although extremely minute ramifications of the trachea were obvious in

every part. Insects, however, both in their perfect and larve state, have a membranous tube running along the back, in which alternate dilatations and contractions are perceptible, and which has been considered as their heart; but it is closed at both ends, and no vessels can be perceived originating from it. To this the innumerable ramifications of the trachea convey the air, and thus, as Cuvier has remarked, "le sang ne pouvant aller chercher l'air, c'est l'air qui va chercher le sang;" ("the blood not being able to go in search of the air—the air seeks the blood.") Carus, however, discovered a continuous circulation through arteries and veins in a few of the perfect insects, and especially in some larves. Lastly: in many genera of the class *vermes*, particularly amongst molluscous animals, there is a manifest heart, which is sometimes of a singular structure. Some of the bivalves—it is affirmed—have as many as four auricles; whilst many animals, as the leech and *Lumbricus marinus*, have no heart; but circulating vessels exist, in which contraction and dilatation are perceptible.

The marginal figure, (Fig. 306,) of the interior of a leech, given by Sir Everard Home, exhibits the mode of circulation and respiration in that animal. There is no heart, but a large vessel exists on each side. The water is received, through openings in the belly, into the cells or respiratory organs, and passes out through the same.

CHAPTER V.

NUTRITION.

The investigation of the phenomena of the circulation has exhibited the mode in which arterial blood is distributed over the body in minute vessels, not appreciable by the naked eye, and often not even with the microscope, and so numerous, that it is impossible for the finest-pointed instrument to be forced through the skin without penetrating one, and perhaps several. It has been seen, likewise, that, in the capillary system of vessels, this arterial blood is changed into venous; and it was observed, that in the same system, parts are deposited or separated from the blood, and certain phenomena occur, into the nature of which we have now to inquire; beginning with those of *nutrition*, which comprise the incessant changes that are taking place in the body, both of absorption and deposition for the decomposition and renovation of each organ. Nutrition is well defined by M. Adelon[1] as the action, by which every part of the body, on the one hand, appropriates or assimilates to itself a portion of the blood distributed to it; and, on the other, yields to the absorbing vessels a portion of the materials that previously composed it. The precise character of the apparatus, by which this important function is accomplished, we have no exact means of knowing. All admit that the old matter must be taken up by absorbents, and the new be deposited by arteries, or by vessels continuous with them. As the precise arrangement of these minute vessels is not perceptible by

[1] Physiologie de l'Homme, tom. iii. p. 359, 2de édit., Paris, 1829.

the eye, even when aided by powerful instruments, their arrangement has given rise to controversy. Whilst some have imagined lateral pores in the capillaries, for the transudation of nutritive deposits; others have presumed, that inconceivably small vessels are given off from the capillary system, which constitute a distinct order, and whose function is to exhale the nutritive substance,—an idea, which, as has been said elsewhere, has been revived by M. Bourgery.[1] Hence, they have been termed *exhalants* or *nutritive exhalants;* but the anatomical and physiological student must bear in mind, that whenever the term is used by writers, they do not always pledge themselves to the existence of any distinct set of vessels, but merely mean the minute vessel, whatever may be its nature, which is the agent of nutrition, and conveys the pabulum to the different tissues.

In investigating the physiology of nutrition, two antagonistic processes demand attention; 1st. *Decomposition*, by which the tissue yields to the absorbing vessels a portion of its constituents; and 2dly. *Composition*, by which it assimilates a part of the arterial blood that enters it, and supplies the loss it had sustained by the previous act of decomposition. The former of these actions obviously belongs to the function of absorption; but its consideration was deferred, in consequence of its close application to the function we are about to investigate. It comprises what is meant by *interstitial*, *organic*, or *decomposing absorption*, and does not require many comments, after the long investigation of the general phenomena of absorption into which we entered. The conclusion, then arrived at, was,—that the chyliferous and lymphatic vessels form only chyle and lymph respectively, refusing the admission of all other substances;—that the veins admit every liquid which possesses the necessary tenuity; and that whilst all the absorptions,—which require the substance acted upon to be decomposed and transformed,—are effected by the chyliferous and lymphatic vessels, those that demand no alteration are accomplished through the coats of the veins by imbibition. It is easy, then, to deduce the agents to which we refer the absorption of decomposition. As it is exerted on solids, and as these cannot pass through the coats of the vessel in their solid condition, it follows that other agents than the veins must accomplish the process; and, again, as we never find in the lymphatic vessels any thing but lymph, and have every reason to believe, that an action of selection is exerted at their extremities, similar to that of the chyliferous vessels on the heterogeneous substances exposed to them, we naturally look to the lymphatics as the main, if not the sole, organs concerned in the absorption of solids.

It has been maintained, by some physiologists, that the different tissues are endowed with a vital attractive and elective force, which they exert upon the blood;—that each tissue attracts only those materials of which it is itself composed; and thus, that the whole function of nutrition is an affair of elective affinity; but this, obviously, cannot be the force that presides over the original formation of the tissues in the embryo. An attraction cannot be exerted by parts not yet in existence.

[1] See page 92 of this volume.

To account for this, it has been imagined, that a peculiar force is destined to preside over formation and nutrition, and various names have been assigned to it. By most of the ancients it was termed *facultas formatrix, nutrix, auctrix;* by Van Helmont,[1] *Blas alterativum;* and by Bacon,[2] *motus assimilationis.* It is the *facultas vegetativa* of Harvey;[3] the *anima vegetativa* of Stahl;[4] the *puissance du moule intérieur* of Buffon;[5] the *vis essentialis* of C. F. Wolff;[6] and the Bildungstrieb or *nisus formativus* of Blumenbach and most German writers.[7] This force is meant, when writers speak of *germ force, plastic force, force of nutrition, force of formation,* and *force of vegetation.* Whatever difference there may be in the terms selected, all appear to regard it as charged with maintaining, for a certain length of time, living bodies and all their parts, in the possession of their due composition, organization, and vital properties; and of putting them in a condition, during a certain period of their existence, to produce beings of the same kind as themselves. It is obvious, however, that none of these terms elucidate the intricate phenomena of nutrition, and none express more than—that living bodies possess a *vital force,* under the action of which, formation and nutrition are accomplished.

The important—indispensable actions—that constitute nutrition occur in the tissues supplied by the intermediate or capillary system of vessels; but not in those vessels themselves. Their function is to convey to the system of nutrition the pabulum or material from which the tissues are formed; but the formation of the tissues takes place on the outside of the vessel; and the organic cells are the immediate agents. It is not, however, the whole of the circulating fluid that constitutes such pabulum. The blood corpuscles—excepting in a single case, menstruation—are not found outside the vessels in the exercise of the healthy functions. The liquor sanguinis alone transudes, and is the material on which the nucleated cell exerts its plastic power.[8]

Under the idea that all the vessels of the capillary system are possessed of coats, it is not so easy to comprehend how either nutrition or secretion can be accomplished. Were we to adopt the opinion, before referred to, that many of the vessels of the capillary system consist of membraneless or coatless tubes, it would be more readily understood, that by the elective and attractive forces possessed by the tissues and exerted by them on the blood, materials may be obtained from that fluid as it passes through the intermediate system of vessels, which may be inservient to the nutrition of the tissues bathed by it. The mode in which the blood is distributed through the tissues may be likened to the distribution of the water of a river through a marsh, which conveys to the animal and vegetable bodies that flourish in it the materials for their nutrition. To adopt the language of an

1 Opera, pars i.
2 Novum Organum, lib. ii., aphor. 48.
3 De Generatione Animalium, Lond., 1651, p. 170.
4 Theoria Medica Vera. Hal., 1708.
5 Histoire Naturelle, tom. ii.
6 De Generatione, Hal., 1759.
7 Comment. Societ. Gotting., tom. viii.; and Institutiones Physiologicæ, § 31, Gotting., 1798.
8 Mulder, The Chemistry of Vegetable and Animal Physiology, translated by Fromberg, p. 597, Edinburgh and London, 1849.

intelligent and philosophical writer,[1] "In every part of the body, in the brain, the heart, the lung, the muscle, the membrane, the bone, each tissue attracts only those constituents of which it is itself composed. Thus the common current, rich in all the proximate constituents of the tissues, flows out to each. As the current approaches the tissue, the particles appropriate to the tissue feel its attractive force, obey it, quit the stream, mingle with the substance of the tissue, become identified with it, and are changed into its own true and proper nature. Meantime, the particles which are not appropriate to that particular tissue, not being attracted by it, do not quit the current, but, passing on, are borne by other capillaries to other tissues, to which they are appropriate, and by which they are apprehended and assimilated. When it has given to the tissues the constituents with which it abounded, and received from them particles no longer useful, and which would become noxious, the blood flows into the veins, to be returned by the pulmonic heart to the lung, where, parting with the useless and noxious matter it has accumulated, and replenished with new proximate principles, it returns to the systemic heart, by which it is again sent back to the tissues." Particles of blood are seen to quit the current and mingle with the tissues; particles are seen to quit the tissues, and mingle with the current; but all that we can see, as Dr. Smith has remarked, with the best aid we can get, does but bring us to the confines of grand operations, of which we are altogether ignorant. It would not seem, however, to be necessary for the nutrition of certain parts, that they should receive capillary vessels. There are tissues, commonly termed extra-vascular, in the substance of which neither injection nor the microscope has exhibited the existence of bloodvessels, and which would seem to derive their nourishment by imbibition from blood flowing in the vessels of adjacent tissues. To these belong the crystalline body, epidermis and epithelium, hair, nails, enamel of the teeth, &c., &c.

We have said that the main, if not the sole, agents of the absorption of solids are the lymphatics. Almost all admit, that they receive the products of the absorption of solids; but all do not admit, that the action of taking up solid parts is accomplished immediately by the absorbents. They who think, that a kind of spongy tissue or "parenchyma" exists at the radicles of the absorbent vessels, believe that this sponge possesses a vital action of absorption, when bodies, possessing the requisite constitution and consistence, are put in contact with it; but they maintain, that the solid parts are broken down by the same agents—the extreme arteries—which secreted them, and that, when reduced to the proper fluid condition, they are imbibed by the parenchyma, and conveyed into the lymphatics. But if the existence of this sponge were demonstrated, the above explanation would scarcely be admissible, for the sponge could not be conceived to do more than imbibe; it could not break down solids, and reduce them to lymph—the only fluid which, as we have seen, is ever met with in lymphatics. Its existence is, however, altogether supposititious. Besides, the arrangement has not been invoked in favour of the chyliferous vessels, which are so analogous in their organization and functions to the lymphatics. It has not been

[1] The Philosophy of Health, by Dr. Southwood Smith, vol. i. p. 405, London, 1835.

contended, that the arteries of the intestinal canal form the chyle from the alimentary matters in the small intestine, and that the office of the chyliferous vessels is restricted to the reception of this chyle, imbibed and brought in contact with their radicles by the ideal sponge or parenchyma.

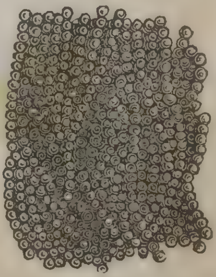
We have before shown, that there is every reason for the belief, that a vital action of selection and elaboration exists at the very origin of the chyliferous vessels; and the same may be inferred of the lymphatics. The great difficulty has been to understand how either exhaling artery or absorbing lymphatic can reduce the solid matter—of bone, for example—to the constitution and consistence requisite for entering the lymphatics; but we might conceive, that the latter as readily as the former, by virtue of its vital properties—for the operation must be admitted by all to be *vital*—and by means of its contained fluid, might soften the solid so as to admit of its being received into the vessel. We should still, however, have to explain the mysterious operation by which those absorbents are enabled to reduce to their elements, bone, muscle, tendon, &c., and to recompose them into the form of lymph. Dr. Bostock[1] fancifully suggests, that the first step in this series of operations is the death of the part; by which expression he means, that it is no longer under the influence of arterial action. "It therefore ceases to receive the supply of matter which is essential to the support of all vital parts, and the process of decomposition necessarily commences." The whole of his remarks on this subject are eminently gratuitous, and appear to be suggested by an extreme unwillingness to ascribe the process to any thing but physical causes. If there be, however, any one phenomenon of the animal economy, which is more manifestly referable to vital action than another, it is the function of nutrition, both as regards the absorption of parts already deposited, and the exhalation of new. We know that the blood contains most of the principles that are necessary for the nutrition of organs, and that it must contain the elements of all. Fibrin, albumen, fat, osmazome, salts, &c., exist in it, and these are deposited, as the blood traverses the tissues; but why one of these should be selected by one set of vessels, and another by another set, and in what manner the elements of those, not already formed in the blood, are brought together, is unknown to us. Blood has been designated as "liquid flesh,"—*chair coulante*,—but something more than simple transudation through vessels is necessary to form it into flesh, and to give it the compound organization of fibrin, gelatin, osmazome, &c.—in the form of muscular fibre and areolar membrane—as we observe in the muscle. Nothing, perhaps, has more clearly exhibited the want of knowledge on this subject than the following vague attempt at solving the mystery by one of the most distinguished physiologists of the age. "Some immediate principles, that enter into the composition of the organs or of the fluids, are not found in the blood,—such as gelatin, uric acid, &c. They are consequently formed at the expense of other principles, in the parenchyma of the organs, and by a chemical action, the nature of which is unknown to us, but which is

[1] System of Physiology, edit. cit., p. 625.

not the less real, and must necessarily have the effect of developing heat and electricity."

The views of recent histologists have approximated us more to a true knowledge of this mysterious action. They have not been content with endeavouring to reduce the different organized textures to primary fibres and filaments, but, by the aid of the microscope, have attempted to discover the particular arrangement and mode of formation of the constituent corpuscles. The discovery of that valuable instrument gave the impulse; and very soon the scientific world was presented with the results obtained by numerous observers. These observations have been, from time to time, continued until the present day. It is, however, to be regretted, that, until recently, our information, derived from this source, was not as accurate as was desirable. From different quarters, the most discordant statements were presented, exhibiting clearly, either that the narrators employed instruments of very different powers, or that they were blinded, or had the vision depraved, by preconceived theories or hypotheses. One of the very first effects of the discovery of the microscope was the detection by Leeuenhoek,[1] of a globular structure of the primitive tissues of the body, an announcement which gave rise to much controversy, and has engaged the attention particularly of Prochaska,[2] Fontana,[3] Sir Everard Home, Mr. Bauer, the brothers Wenzel,[4] M. Milne Edwards, MM. Prévost and Dumas,[5] Dutrochet, Hodgkin,[6] Raspail, and others.[7] The observations and experiments of Dr. Edwards, more especially, occasioned at the time much interesting speculation and inquiry. They may perhaps be taken as the foundation on which the believers in the globular structure of later years rested their opinions. His views were first published in 1823, in a communication, entitled "*Mémoire sur la Structure élémentaire des principaux Tissues Organiques des Animaux;*" and in a second article in the *Annales des Sciences Naturelles*, for December, 1826, entitled "*Recherches microscopiques sur la Structure intime des Tissues Organiques des Animaux.*" He examined all the principal textures of the body, the areolar tissue, membranes, tendons, muscular fibre, nervous tissue, skin, coats of the blood-vessels, &c. When the areolar tissue was viewed through a powerful lens, it seemed to consist of cylinders; but, by using still higher magnifying powers, these cylinders were found to be formed of rows of globules of the same size, that is, about the $\frac{1}{7500}$th or $\frac{1}{8000}$th of an inch in diameter (Fig. 307); separated from each other, and lying in various directions; crossing and interlacing; some of the rows straight; others bent, and

Fig. 307.



Areolar Tissue (Edwards.)

[1] Opera Omnia, Lugdun. Batav., 1722.
[2] De Structurâ Nervorum, Vind., 1779.
[3] Sur les Poisons, ii. 18.
[4] De Structurâ Cerebri, Tubing., 1812.
[5] Bibliothèque Universelle des Sciences et Arts, t. xvii.
[6] In Drs. Hodgkin's and Fisher's translation of W. Edwards, Sur les Agens Physiques, Lond., 1832.
[7] Klencke, Ueber das Physiologische und Pathologische Leben der Mikropischenzellen, Jena, 1844.

some twisted, forming irregular layers united by a kind of network. The membranes, which consist of areolar tissue, were found to present exactly the same kind of arrangement. The muscular fibre, when examined in like manner, was found to be formed of globules also $\frac{1}{8000}$th part of an inch in diameter. Here, however, the rows of globules are always parallel. The fibres never intersect each other like those of areolar tissue, and this is the only discernible difference,—the form and size of the globules being alike. The size of the globules, and the linear arrangement they assume, seemed to be the same in all animals that possess a muscular structure. (Fig. 308.)

The nervous structure has, by almost all observers, been esteemed globular—and a recent observer[1] has satisfied himself that this is certainly the most uniform appearance. The examination of M. Edwards yielded similar results. It seemed to be composed of lines of globules of the same size as those that form the areolar membrane and muscles; but holding an intermediate place as to the regularity of their arrangement, and having a fatty matter interposed between the rows. In regard to the size of the globules, however, M. Edwards differed materially from an accurate and experienced microscopic observer, Mr. Bauer, who asserted that the cerebral globules are of various sizes. (Fig. 309.) From the results of his own diversified observations, M. Edwards concluded, that "spherical corpuscles, of the diameter of $\frac{1}{300}$th of a millimètre, constitute by their aggregation all the organic textures, whatever may be the properties, in other respects, of those parts, and the functions for which they are destined."

Fig. 308.

Muscular Tissue. (Edwards.)

The harmony and simplicity, which would thus seem to reign through the structures of the animal body, attracted great attention to the labours of M. Edwards. The vegetable kingdom was subjected to equal scrutiny; and—what seemed still more astounding—it was affirmed, that the microscope proved it also to be constituted of globules precisely like those of the animal, and of the same magnitude, $\frac{1}{8000}$th of an inch in diameter; hence, it was assumed, that all organized bodies possess the same elementary structure, and of necessity, that the animal and the vegetable are readily convertible into each other under favourable circumstances, and differ only in the greater or less complexity of their organization. Independently of all other objections, however, the animal differs, as we have seen, from the vegetable, in composition; and this difference must exist not only in the whole, but in its parts; so that, even were it demon-

Fig. 309.

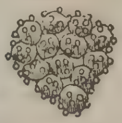
Nervous Tissue. (Edwards.)

[1] Calori, in Bulletino dello Scienze Medich. di Bologna, Sett., 1836, p. 152.
[2] Philosoph. Transact. for 1818; Sir E. Home, Lectures on Comparative Anatomy, vol. iii. lect. 3, Lond., 1823.

strated that the globules of the beings of the two kingdoms are alike in size, it would by no means follow that they should be identical in intimate composition.

The discordance, which we have deplored, is strikingly applicable to the case before us. The appearance of the memoir of Dr. Edwards excited the attention of M. Dutrochet, and in the following year his "*Recherches*" on the subject were published, in which he asserts, that the globules, which compose the different structures of invertebrated animals, are considerably larger than those of the vertebrated; that the former appear to consist of cells, containing other globules still smaller; and hence he infers, that the globules of vertebrated animals are likewise cellular, and contain series of still smaller globules. Dr. Edwards, in his experiments, found, that the globules of the nervous tissue, whether examined in the brain, in the spinal cord, ganglia, or nerves, have the same shape and diameter, and that no difference in them can be distinguished from whatever animal the tissue is taken. M. Dutrochet, on the other hand, considers, with Sir Everard Home, and the brothers Wenzel, that the globules of the brain are cellules of extreme minuteness, containing a medullary or nervous substance, which is capable of becoming concrete by the action of heat and acids. This structure, he remarks, is strikingly evidenced in certain molluscous animals; and he instances the small pulpy nucleus, which forms the cerebral hemisphere of *limax rufus*, and *helix pomatia*, and is composed of globular, agglomerated cellules, on the parietes of which a considerable number of globular or ovoid corpuscles are perceptible. (Fig. 310.)

Fig. 310.



Cellules of Brain. (Dutrochet.)

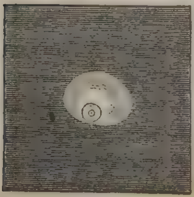
M. Dutrochet, again, did not find the structure of the nerves to correspond with that of the brain. He asserts, that the elementary fibres, which enter into their composition, do not consist simply of rows of globules, according to the opinion of M. Edwards and others, but that they are cylinders of a diaphanous substance, the surface of which is studded with globular corpuscles; and that, as these cover the whole surface of the cylinder, we are led to believe that they are in the interior also. After detailing this difference of structure between the brain and the nerves, the former consisting chiefly of nervous corpuscles, the latter chiefly of cylinders or fibres, M. Dutrochet announces the hypothesis, which exhibits too many indications of having been formed prior to his microscopic investigations,—that these cerebral corpuscles are destined for the production of the nervous power, and that the nervous fibres are tubes, filled with a peculiar fluid, by the agency of which *nervimotion* is effected. For further developements of the views of M. Dutrochet, the reader is referred to the work itself, which exhibits all the author's ingenuity and enthusiasm, but can scarcely be considered historical.

The beautiful superstructure of M. Edwards, and the ingenuity of M. Dutrochet, were, however, most fatally assailed by subsequent experiments of Dr. Hodgkin with a microscope of unusual power. The globular structure of the animal tissues, so often asserted, and apparently so clearly and satisfactorily established by M. Edwards, is, as

we are told by Dr. Hodgkin,[1] a mere deception; and the most minute parts of the areolar membrane, muscles, and nerves, were again referred to the striated or fibrous arrangement. A part of the discrepancy between MM. Edwards and Dutrochet may be explained by the fact of the former using an instrument of greater magnifying power than the latter, who employed the simple microscope only; and it was observed, that when the former used an ordinary lens, the arrangement of a tissue appeared cylindrical, which, with the compound microscope, was distinctly globular. The discordance between Messrs. Edwards and Hodgkin was reconcilable with more difficulty. On the whole subject, indeed, minds were kept in a state of doubt, and the rational physiologist waited for ulterior developements. MM. Prévost and Dumas, and M. Edwards, farther affirmed, that all the proximate principles—albumen, fibrin, gelatin, &c.,—assume a globular form, whenever they change from the fluid to the solid state, whatever may be the cause producing such conversion. M. Raspail[2]—a wayward genius, who has quitted the sober pursuit of science, for the uncertainty and turmoil of politics, from which he has suffered greatly—ranged himself among those who considered, that the ultimate structure of all organic textures is vesicular, and that the organic molecule, in its simplest form, is an imperforate vesicle, endowed with the faculty of inspiring gaseous and liquid substances, and of expiring again such of their elements as it cannot assimilate;—properties, which he conceived it to possess under the influence of vitality. His views contain, perhaps, the germ of those that follow, and that now occupy the minds of observers.

The microscopical researches of Schwann and Schleiden[3] led them to affirm, that the new-forming tissues of vegetables originate from a liquid gum or vegetable mucus, and those of animals probably from the liquor sanguinis—which consists essentially of fibrin—after transudation from the capillary vessels. This *matrix*, in a state fully prepared for the formation of the tissue, is termed by them *intercellular substance* and *cytoblastema.* In the first instance, it exhibits minute granular points, which grow and become more regular and defined from the agglomeration of minuter granules around the larger, constituting *nuclei* or *cytoblasts* or *cell-germs*, and having, when fully formed, and in fact formed before them, one or more well-defined bodies within, called *nucleoli.* From the cytoblasts, *cells—primordial* or *germinal cells*—are formed. A transparent vesicle grows over each, and becomes filled with fluid; this gradually extends and becomes so large that the cytoblast appears like a small body within its walls, and hence the cell is said to be *nucleated.* The form of the cells is at first irregular, then more regular, and they are alternately flattened

Fig. 311.

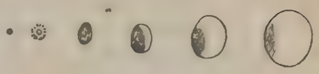


Primary Organic Cell, showing the germinal Cell, Nucleus, and Nucleolus. (Todd and Bowman.)

[1] Op. citat., p. 466. [2] Op. citat., § 126.

[3] Mikroskopische Untersuchungen über die Uebereinstimmung in der Struktur und dem Wachstum der Thiere und Pflanzen, von Dr. Th. Schwann und Schleiden, in Müller's Archiv., p. 137, 1838; and Microscopical Researches into the Accordance and Growth of Animals and Plants, translated by Henry Smith, Sydenham Society edition, London, 1847.

Fig. 312.

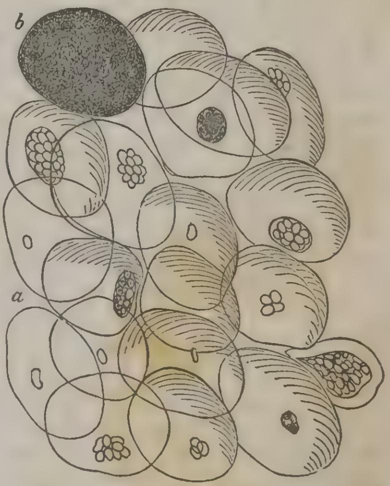


Plan representing the formation of a Nucleus, and of a Cell on the Nucleus, according to Schleiden's view.

by pressure against each other, so as to assume different forms in different tissues. Such is their description of the vegetable cells from which all the tissues of plants take their origin. In like manner, the tissues of animals are formed from a fluid, in which *nucleoli*, *nuclei* or *cytoblasts*—and *cells*, are successively developed. The globules of lymph, pus, and mucus, are cells with their walls distinct and isolated from each other; horny tissues are cells with distinct walls, but united into coherent tissues; bone, cartilage, &c., are formed of cells whose walls have coalesced; areolar tissue, tendon, &c., are cells which have split into fibres, and muscles, nerves, and capillary vessels are cells whose walls and cavities have coalesced.

These cells seem to possess an independent and limited life, which has no immediate connexion with that of the organism; the decomposition constantly taking place in the living body being connected with the death of the cells of which the several parts are constructed; and for the reintroduction of which into the circulating fluid, the lymphatic system appears to be specially destined. By virtue of this vital power, they not only attract but change the substances brought in contact with them, or have a power of self-nutrition; and that this is probably independent of the nervous system is shown by an experiment of Dr. Sharpey, in which the reproduction of a portion of the tail of a salamander took place, although it was cut off, after the organ had been completely paralysed by dissecting out at its root a portion of the spinal cord, together with the arches of the vertebræ. To the doctrine of cell formation, Professor Goodsir,[1] of Edinburgh, has, of late years, made several important additions. Amongst other observations, he states, that besides all organs and tissues having their origin in and consisting essentially of simple or developed cells possessed of a special independent vitality, the component cells are divided into numerous departments, each of which consists of several cells arranged round one central or capital cell, which latter is the source whence all the other cells in its own department de-

Fig. 313.



Endogenous Cell-growth in Cells of a Meliceritous Tumour.

a. Cells presenting nuclei in various stages of developement into a new generation. *b*. Parent-cell filled with a new generation of young cells, which have originated from the granules of the nucleus.

[1] Anatomical and Pathological Observations, p. 1, Edinb., 1845.

rived their origin. To each of these several central nucleated cells he gives the name *nutritive centre* or germinal spot. Each nutritive centre possesses the power of absorbing materials of nourishment from the surrounding vessels, and of generating, by means of its nucleus, successive broods of young endogenous cells, which from time to time fill the cavity of the parent cell, and, carrying with them its cell-wall, pass off in certain directions, and under various forms, according to the texture or organ of which the parent forms a part. There are two kinds of nutritive centres,—those peculiar to the textures, and those belonging to organs. The former are in general permanent; the latter peculiar mostly to the embryonic state, and ultimately disappearing; but there is one form in which the nutritive centres are arranged both in healthy and morbid parts, which constitutes what Mr. Goodsir calls a *germinal membrane*. It is only met with on the free surface of organs or parts. It is a fine transparent membrane, consisting of cells arranged at equal and variable distances within it. The centres of these component cells are flattened, so that their walls form the membrane by cohering at their edges, and their nuclei remain in its substance as germinal centres. One surface of the membrane is attached to that of the organ or part, and is, therefore, applied upon a more or less richly vascular tissue; the other is free, and it is to it only that the developed or secondary cells of its germinal spots are attached. These secondary cells, whilst forming, are contained between the two layers of the germinal membrane; but as they become developed, they carry forward the anterior layer, and become attached to the free surface, whilst the nuclei are left in the substance of the posterior layer in close contact with the bloodvessels, from which they derive the materials for the formation of new cells.

The doctrine of the developement of all the organic tissues from cells is now embraced by almost all histological inquirers; yet there are some who doubt it; and others, who by no means regard it as applicable to all the tissues. Thus M. Mandl[1] objects to the term *cytoblastema* as applicable to the matrix or organizing material of the tissues, because it necessarily involves the supposition that it gives origin to cells. According to him, the elements, that are developed in the *blastema*—as he prefers to call it—do not generally deserve the name of cells, inasmuch as they may either liquefy as in the glands; consolidate as in the amorphous membranes; or become transformed directly into fibres, as in the areolar tissue. Mr. Gulliver,[2] too, has inferred from his observations, that the mere extension of the parietes of cells is not essential to the formation of all tissues, since fine fibres or fibrils are found in fibrin that has coagulated even out of the body. He has given several figures to exhibit the analogy of structure between false membranes and fibrin coagulated after death, or after the removal of the blood from the body. Schwann, on the other hand, lays down the rule, which he considers of universal application, that all organic tissues, however different they may be, have one common principle of

[1] Manuel d'Anatomie Générale, p. 549, Paris, 1843.
[2] Appendix to Gerber's Anatomy, Atlas, p. 60, and Figs. 244–6, Lond., 1842.

developement as their basis, the formation of cells;—that is to say, nature never unites molecules immediately into a fibre, tube, &c.; but, always, in the first instance, forms a round cell; or changes, when it is requisite, the cells into the various primary tissues, as they present themselves in the adult state; but "how," says Mr. Gulliver,[1] "is the origin of the fibrils, which I have depicted in so many varieties of fibrin, to be reconciled with this doctrine? and what is the proof that these fibrils may not be the primordial fibres of animal textures? I could never see any satisfactory evidence, that the fibrils of fibrin are changed cells; and indeed, in many cases, the fibrils are formed so quickly after coagulation, that their production, according to the views of the eminent physiologist just quoted [Schwann], would hardly seem possible. Nor have I been able to see, that these fibrils arise from the interior of the blood-disks, like certain fibres delineated in the last interesting researches of Dr. Barry." Mr. T. Wharton Jones,[2] also, has considered the notion entertained by Dr. Barry,[3] that a fibre exists in the interior of the blood corpuscles, and that these fibres, after their escape from them, constitute the fibres which are formed by the consolidation of the fibrin of the liquor sanguinis, to be erroneous. He regards the appearance as altogether illusive. Dr. Carpenter,[4] in remarking on Mr. Gulliver's figures, all of which, as he properly observes, clearly show, that a small portion of coagulated fibrin contains a far larger number of fibres than we can imagine to be contained in the number of blood-disks that would fill the same space, states, that he has discovered a very interesting example of a membrane composed almost entirely of matted fibres, which so strongly resembles the delineations of fibrous coagula given by Mr. Gulliver, that he cannot but believe in the identity of the process by which they are produced. This is the membrane enclosing the white of the egg, and forming the animal basis of the shell. If the shell be treated with dilute acid, a tough membrane remains, exactly resembling that which lines it; and if the hen has not been supplied with lime, there is no difference between the two membranes even without the action of acid on the outer one. Each of them consists of numerous laminæ of most beautifully matted fibres intermixed with round bodies exactly resembling exudation cells. It is in the interstices of these fibres, that the calcareous particles are deposited, which give density to the shell. These membranes, according to Dr. Carpenter, are formed around the albumen, which is deposited on the surface of the ovary during its passage along the oviduct, from the interior of which the fibrinous exudation must take place.

It is clear, then, that this doctrine of the origin of all the tissues from cells cannot be considered established. We believe, indeed, with a recent writer,[5] that most physiologists, who are not prejudiced by the seductive simplicity of Schwann's generalization as to the derivation of

[1] Lond. and Edinburgh Philosoph. Magazine, Oct., 1842.
[2] Proceedings of the Royal Society, No. 56.
[3] Philosophical Transactions for 1842.
[4] Origin and Functions of Cells, in Brit. and For. Med Rev. for Jan., 1843, p. 277.
[5] Brit. and For. Med. Review, July, 1844, p. 95.

all the tissues from cells, have arrived at the conclusion, that as regards the areolar and other simple fibrous tissues, no other explanation of their production need be looked for than the known tendency of the particles of fibrin to arrange themselves in a linear manner so as to form fibres,—a tendency which "manifests itself much more decidedly, when the consolidation takes place upon a living surface than upon a dead one."

Nor can ideas be esteemed more fixed in regard to the character of the matrix or blastema. M. Mandl[1] affirms that we know not whether it is the albumen or fibrin of the blood. Others, and perhaps the majority of the present day, ascribe it to fibrin, between which, as we have elsewhere seen, and albumen, there is, according to Mulder, Liebig, and others, an almost identity of chemical composition. Fibrin, however, is considered to possess much higher vital properties; and the change of albumen into fibrin has been esteemed the first important step in the process of assimilation. In the chyliferous vessels, the proportion of fibrin increases as the chyle and lymph proceed onwards in the vessels; whilst that of the albumen diminishes. Such, however, is not rigorously the fact, for on referring to the table slightly modified from that of Gerber, which has been given elsewhere (vol. i. p. 653), it will be seen, that in the afferent lacteals between the intestines and mesenteric glands, the albumen has been found in *minimum* quantity; in the efferent or central lacteals, from the mesenteric glands to the thoracic duct, in *maximum* quantity; and in the thoracic duct in *medium* quantity; whilst the fibrin goes on progressively increasing as the chyle and lymph proceed onwards. On the other hand, the fat was found to diminish progressively; so that there appears to be more probability that the fibrin is formed from the fat, directly or indirectly, than from the albumen. It would seem not improbable, that some nitrogenized material like pepsin, or diastase in plants, is secreted from the parietes of the chyliferous vessels, which occasions a change in the elements of the constituents of the chyle, and is the earliest step in animalization: and the view is somewhat confirmed by the fact to which attention has been drawn by Mr. G. Ross,[2] that the constituents of fatty matter, added to those of uric acid, would very nearly give the atomic constituents of albumen; whence, as Dr. Carpenter[3] has remarked, it might be surmised, that when there is a demand for proteinaceous compounds in the system, nitrogenized matter, which would otherwise be thrown out of the system, may be united with non-nitrogenized compounds taken as food, in order to supply its wants. That there is an essential physiological difference, however, between fibrin and albumen, notwithstanding their affirmed similarity in chemical composition, is shown by the fact, that effused fibrin has a tendency to spontaneous coagulation, whilst albumen requires the agency of heat; and that, as we have seen, there is an appearance of distinct organization in coagulated fibrin. This difference in properties would necessarily induce the belief, that the two substances differ more perhaps in chemical composition than the results of the analyses of Mulder, Liebig,

[1] Op. cit., p. 548. [2] Lancet, 1842–3, vol. i. [3] Op. cit., p. 492.

and others, would seem to indicate; and such appears to be proved by those of MM. Dumas and Cahours, which have been conducted on a very extensive scale; and show, that the proportion of carbon is seven per cent. less in fibrin than in albumen; whilst that of azote is from eight to nine per cent. more. A correct idea, these gentlemen think, may be formed of the elementary composition of fibrin by considering it a compound of casein, albumen, and ammonia.[1]

A view is entertained by many, that nothing but proteinaceous compounds can serve for the nutrition of the tissues; and that, as before remarked, gelatin is not adapted for this purpose. Liebig suggests, that it may be inservient to the nutrition of the gelatinous tissues; and Dr. Carpenter[2] says, there is no doubt, that it is incapable of being applied to the reconstruction of any but the gelatinous tissues; and that it seems questionable, whether, even in these, it exists in a condition that can rightly be termed organized: yet it appears to the author, that great doubt may be entertained on this subject. The inconclusiveness of the experiments made on gelatin as an article of food has been animadverted on elsewhere (vol. i. p. 547). Although not a proteinaceous compound, it is one that is highly nitrogenized. When used as an aliment, it is not capable of being detected in the chyle or blood, and hence must have undergone a metamorphosis, probably into an albuminous compound; and it is certainly as difficult to comprehend how, under such circumstances, gelatin can be inservient to the nutrition of gelatinous tissues when no gelatin is present in the blood, as to comprehend that it may be converted first into albumen, and afterwards into fibrin. How gelatinous aliment, in other words, is formed into chyle and blood in which gelatin is not discoverable, and from these again gelatinous tissues are re-formed, is as incomprehensible as that any of the proteinaceous tissues should be constituted from the same pabulum; or that oleaginous aliments—as is admitted by some, who deny the same power to the gelatinous—should be convertible into proteinaceous compounds.

Such is the state of uncertainty in which we are compelled to rest in regard to this important function. None of the views can be esteemed established. They are in a state of transition; and all, perhaps, that we are justified in deducing is, that the vital property, which exists in organizable matters—in the fibrinous portion of the blood, and in the blastema furnished by the parents at a fecundating union—gives occasion to the formation of cells, in some cases—of fibres in others; and that the tissues are farther developed through the agency of *cell-life* or *fibre-life*, so as to constitute all the textures of which the body is composed.

It is the action of nutrition, that occasions the constant fluctuations in the weight and size of the body, from the earliest embryo condition till advanced life. The cause of the developement or *growth* of organs and of the body generally, as well as of the limit accurately assigned to such developement, according to the animal or vegetable species, is dependent upon vital laws that are unfathomable. Nor are we able to

[1] Med. Examiner, October 14, 1843, p. 232.
[2] Principles of Human Physiology, 2d edit., p. 476, London, 1844.

detect the precise mode in which the growth of parts is effected. It cannot be simple extension, for the obvious reason that the body and its various compartments augment in weight as well as in dimension. The rapidity with which certain growths are effected is astonishing. The *Bovista giganteum* has been known to increase, in a single night, from a mere point to the size of a large gourd, estimated to contain 48,000,000,000 of cellules; and supposing twelve hours to have been necessary for its growth, the cells in it must have been produced at the rate of 4,000,000,000 an hour, or more than 66,000,000 a minute,—the greater part of the elements necessary for this astonishing formation being obtained from the air.[1] But these rapid growths possess little vitality, and their decay is almost as rapid as their production. Analogous growths—but not to the like extent—occur in the human body, and the same remark applies to them.

In the large trees of our forests we find a fresh layer or ring added each year to the stem, until the full period of developement; and it has been supposed that the growth of the animal body may be effected in a similar manner, both as regards its soft and harder materials,—that is, by layers deposited externally. That the long bones lengthen at their extremities is proved by an experiment of Mr. Hunter.[2] Having exposed the tibia of a pig, he bored a hole into each extremity of the shaft, and inserted a shot. The distance between the shots was then accurately taken. Some months afterwards, the same bone was examined, and the shots were found at precisely their original distance from each other; but the extremities of the bone had extended much beyond their first distance from them. The flat bones also increase by a deposition at their margins; and the long bones by a similar deposition at their periphery,—additional circumstances strongly exhibiting the analogy between the successive developement of animals and vegetables. Exercise or rest; freedom from, or the existence of, pressure, produces augmentation of the size of organs, or the contrary; and there are certain medicines, as iodine, which are said to occasion emaciation of particular organs only—as of the female mammæ. The effect of disease is likewise, in this respect, familiar and striking.[3]

The ancients had noticed the changes effected upon the body by the function we are considering, and attempted to estimate the period at which a thorough conversion might be accomplished, so that not one of its quondam constituents should be present. By some, this was held to be seven years; by others, three. It is hardly necessary to say, that in such a calculation we have nothing but conjecture to guide us. The nutrition of the body and its parts varies, indeed, according to numerous circumstances. It is not the same during the period of growth as subsequently, when absorption and deposition are balanced, —so far at least as concerns the augmentation of the body in one direction. Particular organs have, likewise, their period of developement, at which time the nutrition of such parts must necessarily be

[1] Truman, Food and its Influence on Health and Disease, &c., p. 229, Lond., 1842.

[2] Observations on Certain Parts of the Animal Economy, with notes, by Prof. Owen, Amer. edit., p. 321, Philad., 1840.

[3] The author's General Therapeutics and Mat. Med., 4th edit., ii. 285, Philad., 1850; and his Practice of Medicine, 3d edit., Philad., 1848.

more active,—the organs of generation, for example, at the period of puberty; the enlargement of the mammæ in the female; the appearance of the beard and the amplification of the larynx in the male, &c. All these changes occur after a determinate plan.

The activity of nutrition appears to be increased by exercise, at least in muscular organs; hence the well-marked muscles of the arm in the prize-fighter, of the legs in the dancer, &c. The muscles of the male are, in general, much more clearly defined; but the difference between those of the hard-working female and the inactive male may not be very apparent.

The most active parts in their nutrition are the glands, muscles, and skin, which alter their character—as to size, colour, and consistence—with great rapidity; whilst the tendons, fibrous membranes, bones, &c., are much less so, and are altered more slowly by the effect of disease. A practice, which prevails amongst certain professions and people, would seem, at first sight, to show that the nutrition of the skin cannot be energetic. Sailors are in the habit of forcing gunpowder through the cuticle with a pointed instrument, and of figuring the initials of their names upon the arm in this manner: the particles of the gunpowder are thus driven into the cutis vera, and remain for life. The operation of *tattooing*, or of puncturing and staining the skin, prevails in many parts of the globe, and especially in Polynesia, where it is looked upon as greatly ornamental. The art is said to be carried to its greatest perfection in the Washington or New Marquesas Islands;[1] where the wealthy are often covered with various designs from head to foot; subjecting themselves to a most painful operation for this strange kind of personal decoration. The operation consists in puncturing the skin with some rude instrument, according to figures previously traced upon it, and rubbing into the punctures a thick dye, frequently composed of the ashes of the plant that furnishes the colouring matter. The marks, thus made, are indelible. M. Magendie[2] asks:—"How can we reconcile this phenomenon with the renovation, which, according to authors," (and he might have added, according to himself,) "happens to the skin?" It does not seem to us to be in any manner connected with the nutrition of the skin. The colouring matter is an extraneous sub-

Fig. 314.

Tattooed Head of a New Zealand Chief.

[1] Lawrence, Lectures on Physiology, &c., p. 411, Lond., 1819.
[2] Précis, &c., edit. cit., ii. 483.

stance, which takes no part in the changes constantly going on in the tissue in which it is embedded; and the circumstance seems to afford a negative argument in favour of venous absorption. Had the substance possessed the necessary tenuity, it would have entered the veins like other colouring matters; but the particles are too gross for this, and hence remain free from all absorbing influence.

CHAPTER VI.

CALORIFICATION.

THE function we have now to consider is one of the most important to organized existence, and one of the most curious in its causes and results. It has, consequently, been an object of interesting examination with the physiologist, both in animals and plants; and as it has been presumed to be greatly owing to respiration, it has been a favourite topic with the chemist also. Most of the hypotheses, devised for its explanation, have, indeed, been of a chemical character; and hence it will be advisable to premise a few observations regarding the physical relations of *caloric* or the *matter of heat*,—an imponderable body, according to common belief, which is generally distributed throughout nature. It is this that constitutes the *temperature* of bodies,—by which is meant, the sensation of heat or cold we experience when they are touched by us; or the height at which the mercury is raised or depressed by them, in the instrument called the *thermometer;*—the elevation of the mercury being caused by the caloric entering between its particles, and thus adding to its bulk; and the depression produced by the abstraction of caloric.

Caloric exists in bodies in two states;—in the *free, uncombined* or *sensible;* and in the *latent* or *combined.* In the latter case, it is intimately united with the other elementary constituents of bodies, and is neither indicated by the feelings nor thermometer. It has, consequently, no agency in the temperature of bodies; but, by its proportion to the force of cohesion, it determines their condition;—whether solid, liquid or gaseous. In the former case, caloric is simply interposed between the molecules; and is incessantly disengaged, or abstracted from surrounding bodies; and, by impressing the surface of the body or by acting upon the thermometer, indicates to us their temperature. Equal weights of the same body, at the same temperature, contain the same quantities of caloric; but equal weights of different bodies at the same temperature have by no means the same. The quantity, which one body contains, compared with another, is called its *specific caloric*, or *specific heat;* and the power or property, which enables bodies to retain different quantities of caloric, is called *capacity for caloric.* If a pound of water heated to 156° be mixed with a pound of quicksilver at 40°, the resulting temperature is 152°,—instead of 98°, the exact mean. The water, consequently, must have lost four degrees of temperature, and the quicksilver gained one hundred and twelve; from which we deduce, that the quantity of caloric, capable of raising one pound of

mercury from 40° to 152° is the same as that required to raise one pound of water from 152° to 156°: in other words, that the same quantity of heat, which raises the temperature of a pound of water four degrees, raises the same weight of mercury one hundred and twelve degrees. Accordingly, it is said, that the *capacity* of water for heat is to that of mercury, as 28 to 1; and that the *specific heat* is twenty-eight times greater.

All bodies are capable of giving and taking free caloric; and consequently, all have a temperature. If the quantity given off be great, the temperature of the body is elevated. If it takes heat from the thermometer, it is cooler than the instrument. In inorganic bodies, the disengagement of caloric is induced by various causes,—such as electricity, friction, percussion, compression, the change of condition from a fluid to a solid state; and by chemical changes, giving rise to new compounds, so that the caloric, which was previously latent, becomes free. If, for example, two substances, each containing a certain amount of specific heat, unite, so as to form a compound whose specific heat is less, a portion of caloric must be set free, and this will be indicated by a rise in the temperature. It is this principle, which is chiefly concerned in some of the theories of calorification.

The subject of the equilibrium and conduction of caloric has already been treated of under the sense of Touch (vol. i. p. 136); where other topics were discussed, that bear more or less upon the present inquiry. It was there stated, that inorganic bodies speedily attain the same temperature, either by radiation or conduction; so that the different objects in an apartment exhibit the same degree of heat by the thermometer; but the temperature of animals being the result of a vital operation, they retain the degree of heat peculiar to them with but little modification from external temperature. There is a difference, however, in this respect, sufficient to cause the partition of animals into two great divisions—the *warm-blooded* and *cold-blooded;* the former comprising those whose temperature is high, and but little influenced by that of external objects;—the latter those whose temperature is greatly modified by external influences. The range of the temperature of the warm-blooded—amongst which are all the higher animals—is limited; but of the cold-blooded extensive. The following table exhibits the temperature of various animals in round numbers;—that of man being 98° or 100°, when taken under the tongue. The temperature in the axilla is something less. In the latter situation, M. Edwards[1] found it vary, in twenty adults, from 96° to 99° Fahrenheit, the mean being 97·5°. It would appear, however, to vary at different periods of the day. Hallmann, from his own observations and those of Gierse,[2] found that the temperature of healthy individuals under the tongue was on the average 37° Cent., or 98·66° Fahr.; late in the morning and evening from 36·7° to 36·8° Cent.,—from 98·06° to 98·24° Fahr.; in the forenoon, at 37·3° Cent.—99·14° Fahr.; and in the afternoon, at 37·5° Cent.—99·5° Fahr.

[1] De l'Influence des Agens Physiques, &c., Paris, 1824; or Hodgkin's and Fisher's translation, Lond., 1832.

[2] Henle, Handbuch der rationellen Pathologie, 1 Band. s. 301, Braunschweig, 1846.

ANIMALS.	OBSERVERS.	TEMPERATURE.
Active young horse, four years old,	Metcalfe.[1]	104°
Arctic fox,	Capt. Lyon.[2]	107
Arctic wolf,	Do.	105
Squirrel,	Pallas.[3]	
Hare,	Do.	104
Whale,	Scoresby.[4]	
Arctomys citillus, zizil,—in summer,	Pallas.	103
Do. when torpid,	Pallas.	80 to 84
Goat,	Prévost and Dumas.[5]	103
She goat, three months old,	Metcalfe.	107
Mother of the same, old, and in poor condition,	Do.	104
Bat, in summer,	Prévost and Dumas.	102
Musk,	Do.	
Marmota bobac,—Bobac,	Do.	101 or 102
House mouse,	Do.	101
Arctomys marmota, marmot—in summer,	Do.	101 or 102
Do. when torpid,	Do.	43
Rabbit,	Delaroche.	100 to 104
Tame young rabbit, two months old,	Metcalfe.	108
Polar bear,	Capt. Lyon.	100
Dog,	Martine.[6]	100 to 103
Cat,	Do.	
Swine,	Do.	
Sheep,	Do.	
Ox,	Do.	
A fine active kitten, two months old,	Metcalfe.	105·5
A vigorous cat, nearly full grown,	Do.	104
Mother of the kitten, three years old,	Do.	103·5
A very old cat, said to be in its 19th year,	Do.	102
An active cur dog, three months old,	Do.	106
Guinea-pig,	Delaroche.	100 to 102
Arctomys glis,	Pallas.	99
Shrew,	Do.	98
Young wolf,	Do.	96
Fringilla arctica, Arctic finch,	Braun.[7]	111
Rubecola, redbreast,	Pallas.	
Fringilla linaria, lesser red poll,	Do.	110 or 111
Falco palumbarius, goshawk,	Do.	110
Caprimulgus Europæus, European goat-sucker,	Do.	
Emberiza nivalis, snow-bunting,	Do.	109 to 110
Falco lanarius, lanner,	Do.	109
Fringilla carduelis, goldfinch,	Do.	
Corvus corax, raven,	Despretz.[8]	
Turdus, thrush, (of Ceylon,)	J. Davy.[9]	
Tetrao perdrix, partridge,	Pallas.	
Anas clypeata, shoveler,	Do.	108
Tringa pugnax, ruffe,	Do.	
Scolopax limosa, lesser godwit,	Do.	
Tetrao tetrix, grouse,	Do.	
Fringilla brumalis, winterfinch,	Do.	
Loxia pyrrhula,	Do.	
Falco nisus, sparrowhawk,	Do	
Vultur barbatus,	Do.	

[1] Caloric, its Mechanical, Chemical, and Vital Agencies in the Phenomena of Nature, ii. 567, Lond., 1843.

[2] Parry's Second Voyage to the Arctic Regions.

[3] Nov. Species Quadruped. de Glirium Ordine, Erlang., 1774.

[4] An Account of the Arctic Regions, Edinb., 1820.

[5] Bibliothèque Univers., xvii. 294.

[6] Med. and Philos. Essays, Lond., 1740; and De Similibus Animalibus et Animal. Calore, &c., Lond., 1740.

[7] Nov. Comment. Acad. Petropol., xiii. 419.

[8] Annales de Chimie, xxvi. 337, Amst., 1824.

[9] Edinb. Philos. Journal, Jan., 1826.

ANIMALS.	OBSERVERS.	TEMPERATURE.
Anser pulchricollis,	Do.	107°
Colymbus auritus, dusky grebe,	Do.	
Tringa vanellus, lapwing, (wounded,)	Do.	
Tetrao lagopus, ptarmigan,	Do.	
Fringilla domestica, house-sparrow,	Do.	107 to 111
Strix passerina, little owl,	Do.	106
Hæmatopus estralagus, sea-pie,	Do.	
Anas penelope, wigeon,	Do.	
Anas strepera, gadwall,	Do.	
Pelecanus carbo,	Do.	
Falco ossifragus, sea-eagle,	Pallas.	105
Fulica atra, coot,	Do.	
Anas acuta, pintail-duck,	Do.	
Falco milvus, kite, (wounded,)	Do.	104
Merops apiaster, bee-eater,	Do.	
Goose,	Martine.	103 to 107
Hen,	Do.	
Dove,	Do.	
Duck,	Do.	
Ardea stellaris,	Pallas.	103
Falco albicollis,	Do.	
Picus major,	Do.	
Cossus ligniperda,	Schultze.	89 to 91
Shark,	J. Davy.	83
Torpedo Marmorata,	Rudolphi.[1]	74

It will be observed, that according to this table the inhabitants of the Arctic regions—whether belonging to the class of mammalia or birds—are among those whose temperature is highest. That of the Arctic fox is probably higher than given in the table, as it was taken after death, when the temperature of the air was as low as —14° of Fahrenheit, and when loss of heat may be supposed to have occurred rapidly.

It is, of course, impracticable to mark the temperature of the smaller insects, but we can arrive at an approximation in those that congregate in masses, as the bee and the ant; for it is difficult to suppose with Miraldi, that the augmented temperature is dependent upon the motion and friction of the wings and bodies of the busy multitudes. Juch[2] found, when the temperature of the atmosphere was —18° of Fahrenheit, that of a hive of bees 44°: in an ant-hill, the thermometer stood at 68° or 70°, when the temperature of the air was 55°; and at 75°, when that of the air was 66°; and Hausmann[3] and Rengger[4] saw the thermometer rise when put into narrow glasses in which they had placed scarabæi and other insects.[5] Berthold detected the elevation of heat only when several insects were collected together, never in one isolated from the rest. This, according to Mr. Newport,[6] must have arisen from his having ascertained the temperature only whilst the insect was in a state of rest; for Mr. Newport found, that although during such a state, the temperature of the insect was very nearly or exactly that of the surrounding medium; yet when it was excited or disturbed, or in a state of great activity from any cause, the thermome-

[1] Grundriss der Physiol., &c., Band. i. 166.
[2] Ideen zu einer Zoochemie, i. 90. [3] De Animal. Exsanguium Respiratione, p. 65.
[4] Physiologische Untersuchung. über die Insecten, p. 40, Tübing., 1817.
[5] Tiedemann, op. citat., p. 511.
[6] Philosoph. Transact. for 1837, part ii. p. 259.

ter rose, in some instances, even to 20° Fahr. above the temperature of the atmosphere,—for instance, to 91°, when the heat of the air was 71°.

The power of preserving their temperature within certain limits is not, however, possessed exclusively by animals. The heat of a tree, examined by Mr. Hunter,[1] was found to be always several degrees higher than that of the atmosphere, when the latter was below 56° of Fahr.; but it was always several degrees below it when the weather was warmer. Some plants develope a great degree of heat during the period of blooming. This was first noticed by De Lamarck[2] in *Arum Italicum*. In *Arum cordifolium*, of the Isle of Bourbon, M. Hubert found, when the temperature of the air was 80°, that of the spathe or sheath was as high as 134°; and M. Bory de St. Vincent[3] observed a similar elevation, although to a less degree, in *Arum esculentum*, *esculent arum* or *Indian kale*. The most exact and elaborate investigations appear to have been made by MM. Vrolik and De Vriese.[4] According to them, the temperature has a regular periodicity within the twenty-four hours, and attains its maximum in the afternoon between the hours of two and five. The difference between the temperature of the atmosphere and that of the root is sometimes as much as from 20° to 30° of Réaumur. According to M. De Saussure, the root of an arum maculatum converted thirty times its volume of oxygen into carbonic acid in twenty-four hours. In all cases, the absolute temperature appeared to depend on the intensity of the vital processes, and was higher in proportion to the vigour of the vegetation in plants, or to the absorption of the sap and the activity of its chemical processes.[5]

The temperature of the animal body is so far influenced by external heat as to rise or fall with it; but the range, as already remarked, is limited in the warm-blooded animal,—more extensive in the cold-blooded. Dr. Currie found the temperature of a man plunged into sea-water at 44° sink, in the course of a minute and a half after immersion, from 98° to 87°: in other experiments, it descended as low as 85°, and even to 83°.[6] It was always found, however, that, in a few minutes, the heat approached its previous elevation; and in no instance could it be depressed lower than 83°, or 15° below the temperature at the commencement of the operation. Similar experiments have been performed on other warm-blooded animals. Mr. Hunter found the temperature of a common mouse to be 99°, that of the atmosphere being 60°: when the same animal was exposed, for an hour, to an atmosphere of 15°, its heat had sunk to 83°;[7] but the depression could be carried no farther. He found, also, that a dormouse,—whose heat in an atmosphere at 64°, was $81\frac{1}{2}$°,—when put into air, at 20°, had its temperature raised in the course of half an hour to 93°; an hour after, the air being at 30°, it was still 93°; another hour after, the air being at 19°, the heat of the

[1] Philos. Transact., 1775 and 1778.

[2] Encyclop. Méthod., iii. 9.

[3] Voyage dans les Quatre Principales Iles des Mers d'Afrique, ii. 66.

[4] Annales de Chimie et de Physique, xxi. 279.

[5] Schleiden, Principles of Scientific Botany, by Dr. Lankester, p. 541, London, 1849.

[6] Philos. Transact. for 1792, p. 199.

[7] Ibid., 1778, p. 21.

pelvis was as low as 83°,—an experiment which strongly proves the great counteracting influence exerted, when animals are exposed to an unusually low temperature. In this experiment, the dormouse had maintained its temperature about 70° higher than that of the surrounding medium, and for the space of two hours and a half. In the hibernating torpid quadruped the reduction of temperature, during their torpidity, is considerable. Jenner[1] found the temperature of a hedgehog, in the cavity of the abdomen, towards the pelvis, to be 95°, and that of the diaphragm 97° of Fahrenheit, in summer, when the thermometer in the shade stood at 78°; whilst in winter, the temperature of the air being 44°, and the animal torpid, the heat in the pelvis was 45°, and that of the diaphragm 48½°. When the temperature of the atmosphere was 26°, the heat of the animal in the cavity of the abdomen, where an incision was made, was reduced as low as 30°; but —what singularly exhibits the power possessed by the system of regulating its temperature,—when the same animal was exposed to a cold atmosphere of 26° for two days, the heat, in the rectum, marked 93°, or 67° above that of the atmosphere. At this time, however, it was lively and active, and the bed on which it lay felt warm. In the cold-blooded animal, we have equal evidence of the generation of heat. Hunter found the heat of a viper, placed in a vessel at 10°, reduced, in ten minutes, to 37°; in the next ten minutes, the temperature of the vessel being 13°, it fell to 35°; and in the next ten, that of the vessel being 20°, to 31°.[2] In frogs, he was able to lower the temperature to 31°; but beyond this point it was not possible to depress it, without destroying the animal.

In the Arctic regions, animal temperature appears to be steadily maintained notwithstanding the intense cold that prevails; and we have already seen, that the animals of those hyperborean latitudes possess a more elevated temperature than those of more genial climes. In the enterprising voyages, undertaken by the British government for the discovery of a northwest passage, the crews of the ships were frequently exposed to the temperature of —40° or —50° of Fahrenheit's scale; and the same thing happened during the disastrous campaign of Russia in 1812, in which so many of the French army perished from cold. The lowest temperature noticed by Captain Parry[3] was —55° of Fahrenheit. Captain Franklin,[4] on the northern part of this continent, observed the thermometer on one occasion—Feb. 7, 1827,—as low as —58° of Fahrenheit. Von Wrangel[5] states that, in January, on the north coast of Siberia, it reaches —59° of Fahrenheit. Captain Back,[6] in his expedition to the Arctic regions of this continent on

[1] Hunter, On the Animal Economy, with Professor Owen's notes, p. 165, Philad., 1840.

[2] Op. citat.

[3] Journal of a Voyage for the Discovery of a Northwest Passage, American edition, p. 130, Philadelphia, 1821.

[4] Narrative of a Second Expedition to the Shores of the Polar Sea, &c., American edition, p. 245, Philadelphia, 1835.

[5] Reise des kaiserlich Russischen Flotten Lieutenants Ferdinand Von Wrangel, längs der Nordküste von Siberien, u. s. w., Berlin, 1839, translated in Harper's Family Library.

[6] Narrative of the Arctic Land Expedition to the mouth of the Great Fish River, &c., in the years 1833, 1834, and 1835, London, 1836.

the 17th of January, 1834, noticed the thermometer at —70° of Fahrenheit. Mr. Erman[1] states, that at Yakutsk it was at —72·5 of Fahrenheit; and Sir George Simpson[2] affirms, that it has fallen in Siberia to —83°, or 115° below the freezing point,—which may be regarded as the greatest depression observed in any climate.

During the second voyage of Captain Parry,[3] the following temperatures of animals, immediately after death, were taken principally by Captain Lyon.

		Temperature of the	
1821.		Animal.	Atmosphere.
Nov. 15.	An Arctic fox	106¾°	— 14°
Dec. 3.	Do.	101½	— 5
	Do.	100	— 3
11.	Do.	101¼	— 21
15.	Do.	99¾	— 15
17.	Do.	98	— 10
19.	Do.	99¾	— 14
1822.			
Jan. 3.	Do.	104½	— 23
9.	A white hare	101	— 21
10.	An Arctic fox	100	— 15
17.	Do.	106	— 32
24.	Do.	103	— 27
	Do.	103	— 27
	Do.	102	— 25
27.	Do.	101	— 32
Feb. 2.	A wolf	105	— 27

These animals must, therefore, have to maintain a temperature at least 100° higher than that of the atmosphere throughout the whole of winter; and it would seem as if the counteracting energy becomes proportionately greater as the temperature is more depressed. It is, however, a part of their nature to be constantly eliciting this unusual quantity of caloric, and therefore they do not suffer. Where animals, not so accustomed, are placed in an unusually cold medium, the efforts of the system rapidly exhaust the nervous energy; and when this is so far depressed as to interfere materially with the function of calorification, the temperature sinks, and the sufferer dies lethargic—or, as if struck with apoplexy. The ship Endeavour, being on the coast of Terra del Fuego, on the 21st of December, 1769, Messrs. Banks, Solander, and others were desirous of making a botanical excursion on the hills on the coast, which did not appear to be far distant. The party, consisting of eleven persons, were overtaken by night, during extreme cold. Dr. Solander, who had crossed the mountains which divide Sweden from Norway, knowing the almost irresistible desire for sleep produced by exposure to great cold, more especially when united with fatigue, enjoined his companions to keep moving, whatever pains it might cost them, and whatever might be the relief promised by an indulgence in rest. "Whoever sits down," said he, "will sleep, and whoever sleeps will wake no more." Thus admonished, they set forward, but whilst

1 Travels in Siberia, translated from the German, by W. D. Cooley, ii. 369, London, 1848.
2 An Overland Journey round the World, Amer. edit., part ii. p. 134, Philad., 1847.
3 Op. citat., p. 157.

still upon the bare rock, and before they had got among the bushes, the cold suddenly became so severe as to produce the effects that had been dreaded. Dr. Solander himself was the first who found the desire irresistible, and insisted on being suffered to lie down. Mr. Banks (afterwards Sir Joseph) entreated and remonstrated in vain. The doctor lay down upon the ground, although it was covered with snow; and it was with the greatest difficulty that his friend could keep him from sleeping. Richmond, one of the black servants, began to linger and to suffer from the cold, in the same manner as Dr. Solander. Mr. Banks, therefore, sent five of the company forward to get a fire ready at the first convenient place they came to; and himself, with four others, remained with the Doctor and Richmond, whom, partly by persuasion and partly by force, they carried forward; but when they had got through the birch and swamp, they both declared they could go no farther. Mr. Banks had again recourse to entreaty and expostulation, but without effect. When Richmond was told, that if he did not go on, he would, in a short time, be frozen to death, he answered, that he desired nothing but to lie down and die. Dr. Solander was not so obstinate, but was willing to go on, if they would first allow him to take some sleep, although he had before observed, that to sleep was to perish. Mr. Banks and the rest of the party found it impossible to carry them, and they were consequently suffered to sit down, being partly supported by the bushes, and, in a few minutes, they fell into a profound sleep. Soon after, some of the people, who had been sent forward, returned with the welcome intelligence, that a fire had been kindled about a quarter of a mile farther on the way. Mr. Banks then endeavoured to rouse Dr. Solander, and happily succeeded; but, although he had not slept five minutes, he had almost lost the use of his limbs, and the soft parts were so shrunk, that his shoes fell from his feet. He consented to go forward with such assistance as could be given him; but no attempts to relieve Richmond were successful. He, with another black left with him, died. Several others began to lose their sensibility, having been exposed to the cold near an hour and a half, but the fire recovered them.

The preceding history is interesting in another point of view besides the one for which it was more especially narrated. Both the individuals, who perished, were blacks; and it has been a common observation, that they bear exposure to great heat with more impunity, and suffer more from intense cold, than the white variety of the species. As regards inorganic bodies, it has been satisfactorily shown, that the phenomena of the radiation of caloric are connected with the nature of the radiating surface; and that those surfaces, which radiate most, possess, in the highest degree, the absorbing power; in other words, bodies that have their temperatures most readily raised by radiant heat are those that are most easily cooled by their own radiation. In the experiments of Professor Leslie[1] it was found, that a clean metallic surface produced an effect upon the thermometer equal to 12; but when covered with a thin coat of glue its radiating power was so far increased as to produce

[1] On Heat, Lond., 1788; and Dr. Stark, in Philosoph. Transact., part ii. for 1833.

one equal to 80; and, on covering it with lampblack, it became equal to 100. We can thus understand why, in the negro, there should be a greater expense of caloric than in the white, owing to the greater radiation; not because as much caloric may not have been elicited as in the white. In the same manner we can comprehend, that, owing to the greater absorbing power of his skin, he may suffer less from excessive heat. To ascertain, whether such be the fact, the following experiments were instituted by Sir Everard Home.[1] He exposed the back of his hand to the sun at twelve o'clock, with a thermometer attached to it, another being placed upon a table with the same exposure. The temperature, indicated by that on his hand, was 90°; by the other, 102°. In forty-five minutes, blisters arose, and coagulable lymph was thrown out. The pain was very severe. In a second experiment, he exposed his face, eyelids, and the back of his hand to water heated to 120°; in a few minutes they became painful; and, when the heat was farther increased, he was unable to bear it; but no blisters were produced. In a third experiment, he exposed the backs of both hands, with a thermometer upon each, to the sun's rays. The one hand was uncovered; the other had a covering of black cloth, under which the ball of the thermometer was placed. After ten minutes, the degree of heat of each thermometer was marked, and the appearance of the skin examined. This was repeated at three different times. The first time, the thermometer under the cloth stood at 91°; the other at 85°; the second time, they indicated respectively 94° and 91°; and the third time, 106° and 98°. In every one of these trials, the skin that was uncovered was scorched; whilst the other had not suffered in the slightest degree. From all his experiments, Sir Everard concludes, that the power of the sun's rays to scorch the skin of animals is destroyed, when applied to a black surface; although the absolute heat, in consequence of the absorption of the rays, is greater.

When cold is applied to particular parts of the body, their heat sinks lower than the minimum of depressed temperature. Although Mr. Hunter was unable to heat the urethra one degree above the maximum of elevated temperature of the body, he succeeded in cooling it 29° lower than the minimum of depressed temperature, or to 58°. He cooled down the ears of rabbits until they froze; and when thawed they recovered their natural heat and circulation. The same experiment was performed on the comb and wattles of a cock. Resuscitation was, however, in no instance practicable where the whole body had been frozen.[2] The same distinguished observer found, that the power of generating heat, when exposed to a cooling influence, was possessed even by the egg. One, that had been frozen and thawed, was put into a cold mixture along with one newly laid. The latter was seven minutes and a half longer in freezing than the former. In another experiment, a fresh-laid egg, and one that had been frozen and thawed, were put into a cold mixture at 15°; the thawed one soon rose to 32°, and began to swell and congeal; the fresh one sank to $29\frac{1}{2}$°, and in twenty-five

[1] Lect. on Comp. Anat., iii. 217, London, 1823.
[2] Sir E. Home's Lect., &c., iii. 438.

minutes after the dead one, rose to 32°, and began to swell and freeze. All these facts prove, that when the living body is exposed to a lower temperature than usual, a counteracting power of calorification exists; but that, in the human species, such exposure to cold is incapable of depressing the temperature of the system lower than about 15° beneath the natural standard. In fish, the vital principle can survive the action even of frost. Captain Franklin found, that those which they caught in Winter Lake, froze as they were taken out of the net; but if, in this completely frozen condition, they were thawed before the fire, they recovered their animation. This was especially the case with a carp, which recovered so far as to leap about with some vigour after it had been frozen for thirty-six hours.

On the other hand, when the living body is exposed to a temperature greatly above the natural standard, an action of refrigeration is exerted; so that the animal heat cannot rise beyond a certain number of degrees; —to a much smaller extent in fact than it is capable of being depressed by the opposite influence. Boerhaave[1] maintained the strange opinion, that no warm-blooded animal could exist in a temperature higher than that of its own body. In some parts of Virginia, there are days in every summer, in which the thermometer reaches 98° of Fahrenheit; and in other parts of this country it is occasionally much higher. The meteorological registers show it to be, at times, at 108° at Council Bluffs, in Missouri; at 104° in New York; and at 100° in Michigan;[2] whilst in most of the states, in some days of summer, it reaches 96° or 98°. At Sierra Leone, Messrs. Watt and Winterbottom[3] saw it frequently at 100°, and even as high as 102° and 103°, at some distance from the coast. Adanson observed it at Senegal as high as 108½°. Sir John Barrow,[4] at the village of Graaff Reynet, in South Africa, noted it on the 24th of November, at 108° in the shade and open air. Brydone affirms, that when the sirocco blows in Sicily the heat rises to 112°.[5] Dr. Chalmers observed a heat of 115°[6] in South Carolina; Humboldt[7] of 110° to 115° in the Llanos or Plains near the Orinoco; and Captain Tuckey asserts, that on the Red Sea he never saw the thermometer at midnight under 94°; at sunrise under 104°; or at midday under 112°. In British India it has been seen as high as 130°.[8]

So long ago as 1758, Governor Ellis[9] of Georgia had noticed how little the heat of the body is influenced by that of the external atmosphere. "I have frequently," he remarks, "walked an hundred yards under an umbrella with a thermometer suspended from it by a thread, to the height of my nostrils, when the mercury has rose to 105°, which

[1] "Observatio docet nullum animal quod pulmones habet, posse in aere vivere, cujus eadem est temperies cum suo sanguine." Element. Chemiæ, i. 275, Lug. Bat., 1732.

[2] Meteorological Register, for the years 1822, 1823, 1824, and 1825, from observations made by the surgeons at the military posts of the United States. See, also, a similar register for the years 1826, 1827, 1828, 1829, and 1830, Philad., 1840.

[3] Account of the Native Africans, vol. i. pp. 32 and 33.

[4] Auto-biographical Memoir, p. 193, London, 1847.

[5] Lawrence's Lectures on Comparative Anatomy, Physiology, &c., p. 306, London, 1819.

[6] Account of the Weather and Diseases of South Carolina, London, 1776.

[7] Tableau Physique des Regions Equatoriales.

[8] Prof. Jameson, British India, Amer. edit., iii. 170, New York, 1832.

[9] Philosophical Transactions, 1758, p. 755.

is prodigious. At the same time I have confined this instrument close to the hottest part of my body, and have been astonished to observe, that it has subsided several degrees. Indeed I could never raise the mercury above 97° with the heat of my body." Two years after the date of this communication, the power of resisting a much higher atmospheric temperature was discovered by accident. MM. Duhamel and Tillet,[1] in some experiments for destroying an insect, that infested the grain of the neighbourhood,—having occasion to use a large public oven, on the same day in which bread had been baked in it,—were desirous of ascertaining its temperature. This they endeavoured to accomplish by introducing a thermometer into the oven at the end of a shovel. On being withdrawn, the thermometer indicated a degree of heat considerably above that of boiling water; but M. Tillet, feeling satisfied, that the thermometer had fallen several degrees in approaching the mouth of the oven, and seeming to be at a loss how to rectify the error, a girl,—one of the servants of the baker, and an attendant on the oven,—offered to enter and mark with a pencil the height at which the thermometer stood within. She smiled at M. Tillet's hesitation in accepting her proposition; entered the oven, and noted the temperature to be 260° of Fahrenheit. M. Tillet, anxious for her safety, called upon her to come out; but she assured him she felt no inconvenience, and remained ten minutes longer, when the thermometer had risen to 280° and upwards. She then came out of the oven, with her face considerably flushed, but her respiration by no means quick or laborious.

These facts excited considerable interest; but no farther experiments appear to have been instituted, until, in the year 1774, Dr. Geo. Fordyce, and Sir Charles Blagden[2] made their celebrated trials with heated air. The rooms, in which these were made, were heated by flues in the floor. Having taken off his coat, waistcoat, and shirt, and being provided with wooden shoes tied on with list, Dr. Fordyce went into one of the rooms, as soon as the thermometer indicated a degree of heat above that of boiling water. The first impression of the heated air upon his body was exceedingly disagreeable; but in a few minutes all uneasiness was removed by copious perspiration. At the end of twelve minutes he left the room very much fatigued; but not otherwise disordered. The thermometer had risen to 220°. In other experiments, it was found, that a heat even of 260° could be borne with tolerable ease. At this temperature, every piece of metal was intolerably hot; small quantities of water, in metallic vessels, quickly boiled; and streams of moisture poured down over the whole surface of his body. That this was merely the vapour of the room, condensed by the cooler skin, was proved by the fact, that when a Florence flask, filled with water of the same temperature as the body, was placed in the room, the vapour condensed in like manner upon its surface, and ran down in streams. Whenever the thermometer was breathed upon, the mercury sank several degrees. Every expiration—especially if made

[1] Mémoir. de l'Académie des Sciences, p. 186, Paris, 1762.
[2] Philosophical Transactions for 1775, p. 111.

with any degree of violence—communicated a pleasant impression of coolness to the nostrils, scorched immediately before by the hot air rushing against them when they inspired. In the same manner, their comparatively cool breath cooled the fingers, whenever it reached them. "To prove," says Sir Charles Blagden, "that there was no fallacy in the degree of heat shown by the thermometer, but that the air which we breathed was capable of producing all the well-known effects of such an heat on inanimate matter, we put some eggs and beef-steak upon a tin frame, placed near the standard thermometer, and farther distant from the cockle than from the wall of the room. In about twenty minutes the eggs were taken out roasted quite hard; and in forty-seven minutes, the steak was not only dressed, but almost dry. Another beef-steak was rather overdone in thirty-three minutes. In the evening, when the heat was still greater, we laid a third beef-steak in the same place; and as it had now been observed, that the effect of the heated air was much increased by putting it in motion, we blew upon the steak with a pair of bellows, which produced a visible change on its surface, and seemed to hasten the dressing: the greatest part of it was found pretty well done in thirteen minutes." In all these experiments, and others of a like kind were made in the following year, by Dr. Dobson,[1] of Liverpool, the heat of the body, in air of a high temperature, speedily reached 100°; but exposure to 212° and more did not carry it higher.

These results are not exactly in accordance with those of MM. Berger and Delaroche,[2] from experiments performed in 1806. Having exposed themselves, for some time, to a stove,—the temperature of which was 39° of Réaumur, or 120° of Fahrenheit—their temperature was raised 3° of Réaumur, or $6\frac{3}{4}$° of Fahrenheit; and M. Delaroche found, that his rose to 4° of Réaumur, or 9° of Fahrenheit, when he had remained sixteen minutes in a stove heated to 176° of Fahrenheit. According to Sir David Brewster,[3]—the distinguished sculptor, Chantry, exposed himself to a temperature yet higher. The furnace which he employed for drying his moulds, was about 14 feet long, 12 high, and 12 broad. When raised to its highest temperature, with the doors closed, the thermometer stood at 350°, and the iron floor was *red-hot*. The workmen often entered it at a temperature of 340°, walking over the floor with wooden clogs, which were, of course, charred on the surface. On one occasion, Sir Francis, accompanied by five or six of his friends, entered the furnace, and after remaining two minutes, brought out a thermometer, which stood at 320°. Some of the party experienced sharp pains in the tips of their ears, and in the septum of the nose, whilst others felt a pain in the eyes. In certain experiments of Chabert, who exhibited his powers as a "Fire King," in this country as well as in Europe, he is said to have entered an oven with impunity, the heat of which was from 400° to 600° of Fahrenheit.

Experiments have shown, that the same power of resisting excessive

[1] Philosophical Transactions for 1775, p. 463.

[2] Expér. sur les Effets qu'une forte Chaleur produit sur l'Economie, Paris, 1805; and Journal de Physique, lxiii. 207, lxxi. 289, and lxxvii. 1.

[3] Letters on Natural Magic, p. 281, Amer. edit., New York, 1832.

heat is possessed by animals. Drs. Fordyce and Blagden shut up a dog, for half an hour, in a room, the temperature of which was between 220° and 236°; at the end of this time a thermometer was applied between the thigh and flank of the animal; and in about a minute the mercury sank to 110°; but the real heat of the body was certainly less than this, as the ball of the thermometer could not be kept a sufficient time in proper contact; and the hair, which felt sensibly hotter than the bare skin, could not be prevented from touching the instrument. The temperature of this animal, in the natural state, is 101°.

We find in organized bodies astonishing cases of adaptation to the medium in which they live. Sonnerat saw, in India, vitex agnus castus flourishing near a spring, whose temperature was 144°; and Foster found it at the foot of a volcano in the Island of Tanna, the temperature of the ground being 176°. Adanson affirms, that different plants vegetate and preserve their verdure in Senegal, although their roots are plunged in sand at a temperature at times as high as 142°; and M. Desfontaines found several plants surrounding the springs at Bonne in Barbary, the heat of which was as high as 171°.[1]

Although man is capable of breathing with impunity air, heated to above the boiling point of water, we have seen, that he cannot bear the contact of water much below that temperature. Yet we find certain of the lower animals—as fish—living in water at a temperature which would be sufficient to boil them if dead. In the thermal springs of Bahia, in Brazil, many small fishes are seen swimming in a rivulet, which raises the thermometer to 88°, when the temperature of the air is only 77½°. Sonnerat found fishes existing in a hot spring at the Manillas, at 158° Fahr.; and MM. Humboldt and Bonpland, in travelling through the province of Quito, in South America, perceived them thrown up alive, and apparently in health, from the bottom of a volcano, in the course of its explosions, along with water and heated vapour, which raised the thermometer to 210°, or only two degrees short of the boiling point.[2] Dr. Reeve found living larvæ in a spring, whose temperature was 208°; Lord Bute saw confervæ and beetles in the boiling springs of Albano, which died when plunged into cold water; and Dr. Elliotson knew a gentleman, who boiled some honey-comb, two years old, and, after extracting all the sweet matter, threw the refuse into a stable, which was soon filled with bees.[3]

When the heating influence is applied to a part of the body only, as to the urethra, the temperature of the part, it has been affirmed, is not increased beyond the degree to which the whole body may be raised.

From all these facts, then, it may be concluded, that when the body is exposed to a temperature greatly above the ordinary standard of the animal, a frigorific influence is exerted: but this is effected at a great expense of vital energy; and hence is followed by considerable exhaustion, if the effort be prolonged. In the cold-blooded animal, the power of resisting heat is not great; so that it expires in water not

[1] Giron de Buzareingues, Précis Elémentaire de Physiologie Agricole, p. 126, Paris, 1849.

[2] Animal Physiology, Library of Useful Knowledge, p. 3.

[3] Physiology, p. 247, Lond., 1840.

hotter than the human blood occasionally is. M. Edwards found that a frog, which can live eight hours in water at 32°, is destroyed in a few seconds in water at 105°: this appears to be the highest temperature that cold-blooded animals can bear. Warm-blooded animals, when exposed to a high temperature, have their temperature increased to a certain extent; but whenever it passes this they perish. M. James[1] took two rabbits, whose normal temperature was about 102·2°, and placed them in two stoves, one at 212°, the other at 140°. The first died sooner than the second; but the temperature of each at the moment of death was the same, 111·2°. The same experiment, over and over again repeated, showed, that whatever might be the degree at which the heat was applied, the animal died when an increase of nine degrees was attained. In birds, whose normal temperature was 111·2°, the same at which the rabbits died, death ensued on the same increase of nine degrees, or when their blood reached 120·2°.

Observation has shown, that although the average temperature of an animal is such as we have stated in the table, particular circumstances may give occasion to some fluctuation. A slight difference exists, according to sex, temperament, idiosyncrasy, &c. MM. Edwards and Gentil found the temperature of a young female half a degree less than that of two boys of the same age. Edwards[2] tried the temperature of twenty sexagenarians, thirty-seven septuagenarians, fifteen octogenarians, and five centenarians, at the large establishment of Bicêtre, and observed a slight difference in each class. Dr. John Davy[3] found, that the temperature of a lamb was a degree higher than that of its mother; and in five new-born children, the heat was about half a degree higher than that of the mother, and it rose half a degree more in the first twelve hours after birth. He subsequently examined the temperature of the aged.[4] In eight old men and women, all, with one exception, between eighty-seven and ninety-five years of age, the temperature under the tongue was 98°, or 98·5°; therefore little, if at all, below the average of adult persons in like circumstances. Two observations, however, showed, that on exposure to external cold, the temperature was more reduced than in young persons. In one case it fell to 95°; in the other to 96·5°. A few observations were also made on persons working in rooms at a temperature of 92°: in one case, the temperature was 100°, in another 100·5°; and in a third, the external temperature being 73°, it was 99°. The same slight variations of the temperature of superficial parts in accordance with changes of external temperature were shown by repeated observations on a healthy man in the different seasons, at Constantinople. By moderate exercise, the temperature on the surface of the extremities was raised—but not above the general average—and was not affected in the internal parts.

Dr. G. C. Holland[5] found that the mean temperature of forty infants exceeded that of the same number of adults by $1\frac{3}{4}$°: twelve of the

[1] Gazette Médicale de Paris, 27 Avril, 1844.
[2] De l'Influence des Agens, &c., p. 436, Paris, 1826.
[3] Philosoph. Transact., p. 602, for 1814.
[4] Philosophical Transactions for 1844, p. 57.
[5] An Inquiry into the Laws of Life, &c., Edinb., 1829.

children had a temperature of from 100° to $103\frac{1}{4}$°. M. Edwards, on the other hand, found, that, in the warm-blooded animal, the faculty of producing heat is less, the nearer to birth; and that, in many cases, as soon as the young dropped from the mother, the temperature fell to within a degree or two of that of the circumambient air; and he moreover affirms, that the faculty of producing heat is at its minimum at birth, and increases successively to the adult age. His trials on children at the large *Hôpital des Enfans* of Paris, and on the aged at Bicêtre, showed, that the temperature of infants, one or two days old, was from 93° to 95° of Fahrenheit; of the sexagenarian from 95° to 97°; of the octogenarian, 94° or 95°; and that, as a general rule, it varied according to age. In his experiments connected with this subject, he discovered a striking analogy between warm-blooded animals in general. Some of these are born with the eyes closed; others with them open: the former, until the eyes are opened, he found to resemble the cold-blooded animal; the latter—or those born with the eyes open—the warm-blooded. Thus, he remarks, the state of the eyes, although having no immediate connexion with the production of heat, may coincide with an internal structure which influences that function, and it certainly furnishes signs, which indicate a remarkable change in this respect; for, at the period of the opening of their eyes, all young mammalia have nearly the same temperature as adults. Now, in accordance with analogy, a new-born infant at the full period, having its eyes open, should have the power of maintaining a pretty uniform temperature during the warm seasons; but if birth should take place at the fifth or sixth month, the case is altered; the pupil is generally covered with the *membrana pupillaris*, which places it in a condition similar to that of closure of the eyelids in animals. Analogy, then, would induce us to conclude, that, in such an infant, the power of producing heat should be inconsiderable, and observation confirms the conclusion; although we obviously have not the same facilities, as in the case of animals, of exposing the infant to a depressed temperature. The temperature of a seven months' child, though well swathed, and near a good fire, was, within two or three hours after birth, no more than 89·6° Fahrenheit. Before the period at which this infant was born, the *membrana pupillaris* disappears; and it is probable, as M. Edwards has suggested, if it had been born prior to the disappearance of the membrane, its power of producing heat might have been so feeble, that it would scarcely have differed from that of mammalia born with the eyes closed.[1]

An extensive series of experiments has been instituted by M. Roger,[1] in regard to the temperature of children in health and various diseases. In nine examinations from one to twenty minutes after birth, the temperature observed in the axilla was from 99·95° to 95·45.° Immediately after birth it was at the highest, but quickly fell to near the lowest point stated above. By the next day, however, it was entirely, or nearly, what it was before. The rapidity of the pulse and respiration appeared to have no certain relation to the temperature. In thirty-

[1] Op. cit. [2] Archiv. Général. de Médecine, Juillet, Août, 1844.

three infants, from one to seven days old, the most frequent temperature was 98·6°; the average 98·75°; the maximum—one case only—was 102·2°; the minimum—also one case—96·8°. All the infants were healthy. The frequency of respiration had no evident or constant relation to the temperature. A few of the infants were of a weakly habit; their average temperature was 97·7°: the others were strong, and their average temperature 99·534°. The age, at this period, had no influence on its temperature; nor had its sex, state of sleeping or waking, nor the period after suckling.

In twenty-four children, chiefly boys, from four months to fourteen years old, the most frequent temperature was above 98·6°; the average 98·978°; the minimum 98·15°; the maximum 99·95°. The average of those six years old, or under, was 98·798°; of those above six years, 99·158°. The average number of pulsations in the minute was, in those under six years, 102; above that age, 77; yet the temperature of the latter was higher than that of the former and of younger infants. There was no evident relation between the temperature and frequency of respiration; nor, in a few examinations, was the temperature affected in a regular way, by active exercise for a short time, or by the stage of digestion.

The state of the system, as to health or disease, also influences the evolution of heat. Dr. Francis Home,[1] of Edinburgh, took the heat of various patients at different periods of their indispositions. He found that of two persons labouring under the cold stage of an intermittent to be 104°; whilst, during the sweat and afterwards, it fell to 101°, and to 99°. The highest, which he noticed in fever, was 107°. The author has witnessed it at 106° in scarlatina and in typhus, but it probably rarely exceeds this, although it is stated to have been as high as 112°;[2] and this is the point designated as "fever heat" on Fahrenheit's scale. M. Edwards alludes to a case of tetanus, in a child, the particulars of which were communicated to him by M. Prévost, of Geneva, in which the temperature rose to 110·75° Fahrenheit.[3] Mr. Hunter[4] found the interior of a hydrocele, on the day of operation, to be 92°; on the following day, when inflammation had commenced, it rose to 99°. The fluid obtained from the abdomen of an individual tapped for the seventh time for ascites indicated a temperature of 101°. Twelve days thereafter, when the operation was repeated for the eighth time, it was 104°. Dr. Granville[5] has asserted that the temperature of the uterus sometimes rises as high as 120°—the elevation seeming to bear some ratio to the amount of action in the organ. The author has frequently been struck with the seemingly elevated temperature of the vagina under those circumstances; but cannot help suspecting inaccuracy in the observations of Dr. Granville, the temperature which he indicates being so much higher than has ever been noticed in any condition of the system. Under this feeling, several experiments were

[1] Medical Facts and Experim., Lond., 1759.
[2] G. T. Morgan's First Principles of Surgery, p. 80, Lond., 1837.
[3] Edwards, op. citat., p. 490.
[4] On the Blood, &c., p. 296, Lond., 1794.
[5] Philos. Transact., p. 262, for 1825; and Sir E. Home, in Lect. on Comp. Anat., v. 201, Lond., 1828.

made, at the author's request, by Dr. Barnes,[1] at the time one of the resident physicians of the Philadelphia Hospital, which exhibit only a slight difference between the temperature of the vagina and that of the uterus during parturition. In two cases, that of the labia was 100°, and in a third 105°; whilst that of the uterus was 100°, 102°, and 106°, respectively. Dr. James Currie had himself bled; and during the operation, the mercury of a thermometer, held in his hand, sank, at first slowly, and afterwards rapidly, nearly 10°; and when he fainted, the assistant found that it had sunk 8° farther. In diseased states, M. Roger[2] found, that the temperature of the skin may descend in children to 74·3°, and rise as high as 108·5°. Its range is, consequently, greater than in adults, in whom M. Andral found it not to vary, in different diseases, more than from 95° to 107·6°. His estimates are, however, much too limited; as in Asiatic cholera the temperature has been marked as low as 67°, whilst in disease it has certainly risen as high as nearly 111°, Fahrenheit. M. Chevallier[3] has investigated the temperature of the urine on issuing from the bladder. This he found was affected by rest, fatigue, change of regimen, remaining in bed, &c. The lowest temperature, which was observed on rising in the morning, was about 92°; the highest, after dinner, and when fatigued, 99°. In the case of another person, the temperature of the urine was never lower than 101°, and occasionally, when fatigued, upwards of 102°.

MM. Edwards and Gentil assert, that they have likewise observed diurnal variations in the temperature, and these produced, apparently, by the particular succession in the exercise of the different organs; as where intellectual meditation was followed by digestion. The variations, they affirm, frequently amounted to two or three degrees, between morning and evening.

Such are the prominent facts connected with the subject of animal heat. It is obvious, that it is disengaged by an action of the system, which enables it to counteract, within certain limits, the extremes of atmospheric heat and cold. The animal body, like all other substances, is subjected to the laws affecting the equilibrium, conduction, and radiation of caloric; but, by virtue of the important function we are now considering, its own temperature is neither elevated nor depressed by those influences to any great extent. Into the seat and nature of this mysterious process, and the various ingenious theories that have been indulged in regard to it, we shall now inquire.

Physiologists have been by no means agreed as to the organs or apparatus of calorification. Some, indeed, have affirmed that there is not, strictly speaking, any such; and that it is a result of all the other vital operations. Amongst those, too, who admit the existence of such an apparatus, a difference of sentiment prevails; some thinking that it is *local*, or effected in a special part of the organism; others, that it is *general*, or disseminated through the whole economy. Under the name *caloricité*, M. Chaussier admitted a primary vital property, by virtue

[1] American Medical Intelligencer, Feb. 15, 1839, p. 346.
[2] Op. cit.
[3] Essai sur la Dissolution de la Gravelle, &c., p. 120, Paris, 1837.

of which living beings disengage the caloric on which their proper temperature is dependent, in the same manner as they accomplish their other vital operations by distinct vital properties; and in support of the views, he adduced the circumstance, that each living body has its own proper temperature;—which is coexistent only with the living state; is common to every living part; ceases at death; and augments by every cause that excites the vital activity. It has been properly objected, however, to this view, that the same arguments would equally apply to many other vital operations,—and that it would be obviously improper to admit, for each of these functions, a special vital property. The notion has not experienced favour from the physiologist, and is, we believe, confined to the individual from whom it emanated.

So striking a phenomenon as animal temperature could not fail to attract early attention; and accordingly, we find amongst the ancients various speculations on the subject. The most prevalent was,—that its seat is in the heart; that the heat is communicated to the blood in that viscus, and is afterwards sent to every part of the system; and that the great use of respiration is to cool the heart. This hypothesis is liable to all the objections that apply to the notion of any organ of the body acting as a furnace,—that such organ ought to be calcined; and it has the additional objection, applicable to all speculations regarding the ebullition and effervescence of the blood as a cause of heat, that it is purely conjectural, without the slightest fact or plausible argument in its favour. It was not, indeed, until the chemical doctrines prevailed, that any thing like argument was adduced in support of the local disengagement of heat: the opinions of physiologists then settled almost universally upon the lungs; and this, chiefly, in consequence of its being observed, that animals, which do not breathe, have a temperature but little superior to the medium in which they live; whilst man and animals that breathe have a temperature considerably higher than the medium heat of the climate in which they exist, and one which is but little affected by changes in the thermal condition of that medium; and, moreover, that birds, which breathe, in proportion, a greater quantity of air than man, have a still higher temperature than he. Mayow,[1] whose theory of animal heat was, in other respects, sufficiently unmeaning, affirmed, that the effect of respiration is not to cool the blood, as had been previously maintained, but to generate heat, which it does by an operation analogous to combustion. It was not, however, until the promulgation of Dr. Black's doctrine of latent heat, that any plausible explanation of the phenomenon appeared. According to that distinguished philosopher, a part of the latent heat of the inspired air becomes sensible; consequently, the temperature of the lungs, and of the blood passing through them, must be elevated; and, as the blood is distributed to the whole system, it must communicate its heat to the parts as it proceeds on its course. But this view was liable to an obvious objection, which was, indeed, fatal to it, and so Dr. Black himself appears to have thought, from his silence on the subject. If the whole of the caloric were disengaged in the lungs, as in a furnace, and were

[1] Tract. quinque, Oxon., 1674.

distributed through the bloodvessels, as heated air is transmitted along conducting pipes, the temperature of the lungs ought to be much greater than that of the parts more distant from the heart; and so considerable as to consume that important organ in a short space of time.

The doctrine, maintained by MM. Lavoisier[1] and Séguin, was;—that the oxygen of the inspired air combines with the carbon and hydrogen of the venous blood, and produces combustion. The caloric given off is then taken up by the bloodvessels, and is distributed over the body. The arguments, which they urged in favour of this view, were:—the great resemblance between respiration and combustion, so that if the latter gives off heat, the former ought to do so likewise;—the generally admitted fact, that arterial blood is somewhat warmer than venous;—and certain experiments of Lavoisier and La Place,[2] which consisted in placing animals in the calorimeter, and comparing the quantity of ice which they melted, and, consequently, the quantity of heat, which they gave off, with the quantity of carbonic acid produced; and finding, that the quantity of caloric, which would result from the carbonic acid formed, was exactly that disengaged by those animals. Independently, however, of other objections, this hypothesis is liable to those already urged against that of Black, which it closely resembles. The objection, that the lungs ought to be much hotter than they really are—both absolutely and relatively—was attempted to be obviated by Dr. Crawford[3] in a most ingenious and apparently logical manner. The oxygen of the inspired air, according to him, combines with the carbon given out by the blood, so as to form carbonic acid. But the specific heat of this is less than that of oxygen; and accordingly, a quantity of latent caloric is set free; and this caloric is not only sufficient to support the temperature of the body, but also to carry off the water—which was supposed to be formed by the union of the hydrogen of the blood and the oxygen of the air—in the state of vapour, and to raise the temperature of the inspired air. So far the theory of Crawford was liable to the same objections as those of Black, and Lavoisier and Séguin. He affirmed, however, that the same process by which the oxygen of the inspired air is converted into carbonic acid, converts the venous into arterial blood; and as he assumed from his experiments, that the capacity of arterial blood for caloric is greater than that of venous, in the proportion of 1·0300 to 0·8928; he conceived, that the caloric, set free in the formation of the carbonic acid, in place of raising the temperature of the arterial blood, is employed in saturating its increased capacity, and maintaining its temperature at the same degree with the venous. According to this view, therefore, the heat is not absolutely set free in the lungs, although arterial blood contains a greater quantity of caloric than venous; but when, in the capillaries, the arterial becomes converted into venous blood, or into blood of a less capacity for caloric, the heat is disengaged, and this occasions the temperature of the body.

Were the facts, which served as a foundation for this beautiful theory

[1] Mém. de l'Acad. des Sciences pour 1777, 1780, and 1790.

[2] Mémoir. de l'Acad. des Sciences pour 1780.

[3] Experiments and Observations on Animal Heat, &c., 2d edit., London, 1788; and Fleming, Philosophy of Zoology, i. 387, Edinb., 1822.

true, the deductions would be irresistible: and, accordingly, it was at one time almost universally received, especially by those who consider, that all vital operations can be assimilated to chemical processes; and it is still favoured by many. "The animal heat," observes a recent writer,[1] "has been accounted for in different ways by several ingenious physiologists: from the aggregate of their opinions and experiments, I deduce, that heat is extricated all over the frame, in the capillaries, by the action of the nerves, during the change of the blood, from scarlet arterial to purple venous; and also whilst it is changing in the lungs from purple to scarlet. There is a perpetual deposition by the capillary system of new matter, and decomposition of the old all over the frame, influenced by the nerves; in this decomposition there is a continual disengagement of carbon, which mixes with the blood returning to the heart, at the time it changes from scarlet to purple; this decomposition, being effected by the electric agency of the nerves, produces a constant extrication of caloric; again, in the lungs that carbon is thrown off and united with oxygen, during which caloric is again set free, so that we have in the lungs a charcoal fire constantly burning, and in the other parts a wood fire, the one producing carbonic acid gas, the other carbon, the food supplying through the circulation the vegetable (or what answers the same end, animal) fuel, from which the charcoal is prepared which is burned in the lung."

Numerous objections have, however, been made against the view of Crawford. In the *first* place, it was objected, that our knowledge is limited to the fact, that oxygen is taken into the pulmonary vessels, and carbonic acid given off, but that we have no means of knowing whether the one goes immediately to the formation of the other. Dr. Crawford had inferred from his experiments, that the specific heat of oxygen is 4·7490; of carbonic acid, 1·0454; of nitrogen, 0·7936; and of atmospheric air, 1·7900; but the more recent experiments of MM. Delaroche and Bérard make that of oxygen, 0·2361; carbonic acid, 0·2210; of nitrogen, 0·2754; and of atmospheric air, 0·2669; a difference of such trifling amount, that it has been conceived the quantity of caloric, given out by oxygen during its conversion into carbonic acid, would be insufficient to heat the residual air in the lungs to its ordinary elevation. *Secondly.* The elevation of temperature of one or two degrees, which appears to take place in the conversion of venous into arterial blood, although generally believed, is not assented to by all (see page 60). The experiments instituted on this point have been few and imprecise; and those of MM. Becquerel and Breschet,[2] made by introducing delicate thermometers into the auricles of the heart of dogs, invariably gave the temperature of arterial, only a few fractions of a degree higher than that of venous, blood. *Thirdly.* M. Dulong,[3]—on repeating the experiments of Lavoisier and La Place, for comparing the quantities of caloric given off by animals in the calorimeter with that which would result from the carbonic acid formed during the same time in their respiration—did not attain a like result. The quantity of caloric disengaged by the animal was always superior to that which

[1] Billing, First Principles of Medicine, 2d edit., p. 19, London, 1837.
[2] Comptes Rendus, Oct., 1841.
[3] Magendie, Journal de Physiologie, iii. 45.

would result from the carbonic acid formed. *Fourthly*. The estimate of Crawford regarding the specific heat of venous and arterial blood has been contested. He made that of the former, we have seen, 0·8928; of the latter, 1·0300. The result of the experiments of Dr. John Davy[1] give 0·903 to the former, and 0·913 to the latter; and in another case, the result of which has been adopted by M. Magendie, the specific heat of venous was greater than that of arterial blood, in the proportion of ·852 to ·839. Granting, however, the case to be as stated by Crawford, it is insufficient to explain the phenomena. It has, indeed, been attempted to show, that if the whole of the caloric, set free in the manner mentioned, were immediately absorbed, it would be insufficient for the constitution of the arterial blood; and that, instead of the lung running the risk of being calcined, it would be threatened with congelation. The theory of combustion is still, however, maintained by many physiologists,[2] and an able writer of this country, Dr. Metcalfe,[3] from a consideration of the various facts observed by himself and others, thinks we are authorized to conclude;—*first*, that during the passage of dark venous blood through the lungs, it gives off variable proportions of carbon and hydrogen, which unite chemically with atmospheric oxygen to form carbonic acid and water as in ordinary combustion, by which it acquires an addition of caloric, and a bright florid hue; and *secondly*, that during its circulation through the systemic capillaries, the caloric obtained from the atmosphere is transferred to the solids, by which their temperature and vitality are maintained; and the blood returns to the heart of a dark modena hue, having lost its power of stimulating the organs, until it acquires an additional quantity of caloric from the lungs.

Dr. Spencer,[4] formerly of Geneva College, N. Y., who regards the great end and function of respiration to be, to aid, both directly and indirectly, in the office of the generation and diffusion of animal heat, maintains, that the substance thrown off from the venous blood in respiration is hydrate of carbon:—that the carbon, on coming in contact with atmospheric oxygen combines with it, forming carbonic acid, which is exhaled from the lungs and skin by expiration and perspiration;—that the amount of latent heat of the oxygen employed is much greater than that of the carbonic acid formed in the lungs, and hence caloric is set free, which imparts heat to the blood and surface; that this free heat also combines with the water of the hydrate of carbon and converts it into vapour;—that the lungs and cutaneous surface aid in regulating animal temperature by the conversion of water into vapour, thus conveying off any excess of free caloric in the system, by combining with it in the form of latent heat;—that the water of the hydrate of carbon is converted into vapour in the lungs, and upon the surface, precisely as when wood is burned, and hence assumes the form of insensible respiratory and perspiratory transpiration;—and that the systemic red

[1] Philos. Transactions for 1814.

[2] Nasse, Art. Thierische Wärme, in Wagner's Handwörterbuch der Physiologie; 23ste Lieferung, s. 1, Braunschweig, 1849.

[3] Caloric, its Mechanical, Chemical, and Vital Agencies, &c., ii. 555, London, 1843.

[4] Lectures on Animal Heat, Geneva, N. Y., 1845.

capillaries are the antagonists of the pulmonary; and are constantly decomposing carbonic acid, and forming, with water, hydrate of carbon,—or, in other words, carbonizing the blood; from which union water and carbonic acid are transformed into a solid substance, and hence latent becomes free heat, at every point where red blood circulates. The views of Dr. Spencer are ingenious, but far from convincing; and are presented by him, although aphoristically, in some detail. He objects to the view, which holds that hydro-carbon is thrown off from the blood in the lungs by its union with oxygen, because hydro-carbon is an imaginary compound. The same objection, however, applies to his hydrate of carbon, which, he thinks, exists in the blood in the solid state, and is analogous to, if not identical with, the lignin of vegetables. In regard to his opinion, that the systemic red capillaries are the antagonists of the pulmonary capillaries, it must not be forgotten, that there are also red capillaries in the lungs; and that in the system of nutrition every where arterial is converted into venous blood; and doubtless with the same phenomena.

The combustion theory has received the powerful support of Liebig, and many elucidations and expansions from that distinguished chemist. According to him, the carbon and hydrogen of the food, in being converted, through the agency of oxygen, into carbonic acid and water, must give out as much heat as if these gases were burned in the open air. The temperature of the human body is essentially the same in the torrid as in the frigid zone; but as the body may be regarded in the light of a heated vessel, which cools with the greater rapidity the colder the surrounding medium, the fuel, necessary to maintain its heat, must vary in different climates. How unequal must be the loss of heat at Palermo, where the external temperature is nearly equal to that of the body, and in the polar regions, where the external temperature is from 70° to 90° lower. In the animal body, food is fuel, and with a proper supply of oxygen we obtain the heat during its oxidation or combustion. In winter, when we take exercise in a cold atmosphere, and the amount of inspired oxygen consequently increases, the necessity for food containing carbon and hydrogen increases in the like ratio, and, by gratifying the appetite thus excited, we obtain the most efficient protection against piercing cold. A starving man is soon frozen to death; and every one, says Liebig, knows, that the animals of prey in the Arctic regions far exceed those of the torrid zone in voracity. Our clothing is merely an equivalent for a certain amount of food. Were we to go naked, like certain savage tribes, or exposed in hunting or fishing to the same degree of cold as the Samoyedes, we should be able to consume with ease sixteen pounds of flesh, and perhaps a dozen tallow candles, as travellers have related of those people. We should, also, be able to take the same quantity of brandy or train-oil without bad effects, because the carbon and hydrogen of these substances would only suffice to keep up the equilibrium between the external temperature and that of our bodies. The whole process of respiration, he thinks, is clearly exhibited when we view the condition of man or animals under abstinence from food. Oxygen is abstracted from the air, and carbonic acid and water expired, because the number of respirations

remains unaltered. With the continuance of the abstinence the carbon and hydrogen of the body diminish. The first effect of abstinence is the disappearance of the fat, which can be detected neither in the scanty fæces nor urine; its carbon and hydrogen are thrown off by the skin and lungs, in the form of a compound with oxygen. These constituents, then, have served for the purposes of respiration. Every day, $32\frac{1}{2}$ ounces of oxygen are inspired; and these must remove their equivalents of carbon to form carbonic acid. When this combination ceases to go on, respiration terminates: death has ensued. The time required for starving an animal to death depends on its fatness, state of activity, the temperature of the air, and the presence or absence of water. That the quantity of heat evolved by the combustion of 13·9 ounces of carbon is amply sufficient to account for the temperature of the human body, may be estimated by figures. An ounce of carbon burned, according to the experiments of Despretz, would evolve 14067 degrees of heat; and 13·9 oz. would, therefore, give out 195531·3 degrees of heat. This would suffice to boil 67·9 pounds of water at 32°, or to convert 11·4 pounds of water at 98·3° into vapour. If we consider the quantity of water vaporized through the skin to be, in twenty-four hours, 48 ounces or 3 pounds, there will then remain, after deducting the necessary amount of heat, 144137·7 degrees of heat, which are dissipated by radiation in heating the expired air, and in excrementitious matters.[1]

These views of Liebig necessarily attracted the devout attention of the chemical physiologist, and whilst they have met with unqualified support from some, they have been as much condemned by others, who appear to have a horror at the introduction of chemical explanations to account for vital phenomena. Yet it cannot be contested, that the function of calorification is an act of vital chemistry; and, consequently, although the views of Liebig may fail to convince, they certainly have taken the proper direction, and, all must admit, have been plausibly and ably supported. It has been objected, that if even his theory were allowed to be applicable to mammalia, birds, and reptiles, it by no means follows, that it should be so to animals that respire by means of branchiæ or gills, all of which consume little oxygen, comparatively speaking; yet many of them devour enormous quantities of food. Even the largest and most voracious of the reptiles, as alligators, crocodiles, &c., under a burning climate too, breathe feebly with their vesicular lungs, and consume but little oxygen. Fishes, too, whose blood is but imperfectly oxygenized by their branchial apparatus, are perhaps amongst the most voracious of animals; yet, according to this theory, they ought to eat little, because they consume little oxygen. These and other facts were eagerly urged by M. Virey,[2] as objections to the views of the Professor of Giessen. It may be replied, however, that in such cases, a large portion of the carbon must pass off in the excrements. There is no country in the world, according to Madame Calderon de la Barca,[3] where so much animal food is consumed as in

[1] Animal Chemistry, Amer. edit. by Webster, p. 33, Cambridge, 1842.
[2] Journal de Pharmacie, Mai, 1842.
[3] Life in Mexico, vol. i. p. 152, Boston, 1842.

Mexico, "and there is no country in which so little is required." To this and to want of exercise she ascribes the early fading of beauty in the higher classes, the decay of teeth, and the over-corpulency so common amongst them; and in regard to the last she is, doubtless, correct.

To the statement of Liebig respecting the greater voraciousness of the animals of prey of the Arctic regions, it has been replied,[1] that a Bengal tiger or Cape hyena requires, in proportion to its size, quite as much aliment as any of the Arctic carnivora; and that the vultures of Hindostan and Persia exceed, perhaps, all other animals in gluttony. The voraciousness of the shark, too, even within the tropics, is proverbial. "Those who ride over the Pampas in South America," says Dr. Graves, "at the rate of one hundred miles a-day, exposed to a burning sun, subsist entirely on boiled beef and water, without a particle of vegetable food of any kind, and yet they attain to an extraordinary *condition*, and capability of enduring violent and long-continued exertion. Liebig's theory must be very ductile, if it can explain how it happens, that an exclusively animal diet agrees with man quite as well at the equator as within the Arctic circle."[2] Numerous facts, indeed, can be brought forward of an opposite tendency to those of Liebig, which render it impracticable for us, in the present state of our knowledge, to embrace all his positions. Under Respiration, the theory, supported by him, that the blood corpuscles are the carriers of oxygen from the lungs to the tissues, and the conveyers of carbonic acid back from the tissues to the lungs, was mentioned. Were this view tenable it would seem, that if the amount of blood corpuscles should become diminished from any cause, the function of calorification ought to be impaired to a like extent. To discover what effect would be produced on the temperature of the living body by a diminution in the quantity of blood corpuscles, M. Andral instituted some experiments, which showed, that the temperature remained normal, even in cases in which the corpuscles had experienced the greatest diminution in number. In the axilla, the temperature was 98° or 99° of Fahrenheit in persons, the proportion of whose blood corpuscles was not higher than 50, 40, 30, and even 21 parts in the 1000; the healthy ratio being 127. Indeed, notwithstanding the great depression in anæmic patients, the heat rose, as usual, when they were attacked with fever, to which they are as subject as other individuals.[3]

But the combustion theories of calorification were most seriously assailed by experiments, tending to show, that the function of calorification is derived from the great nervous centres. When an animal is decapitated, or the spinal marrow, or the brain, or both, are destroyed, the action of the heart may still be kept up, provided the lungs be artificially inflated. In such case, it is found, that the usual change in the blood, from venous to arterial, is produced; and that oxygen is absorbed and carbonic acid exhaled as usual. Sir Benjamin Brodie,[4] in performing this experiment, directed his attention to the point—whe-

[1] R. J. Graves, a System of Clinical Medicine, p. 57, Dublin, 1843.
[2] See, on all this subject, Metcalfe on Caloric, vol. ii. chap. 2, London, 1843.
[3] Andral, Hématologie Pathologique, p. 60, Paris, 1843.
[4] Philos. Trans. for 1811 and 1812.

ther animal heat be evolved under such circumstances, and the temperature maintained, as where the brain and spinal marrow are entire—and he found, that although the blood appeared to undergo its ordinary changes, the generation of animal heat seemed to be suspended; and consequently, if the inspired air happened to be colder than the body, the effect of respiration was to cool the body; so that an animal, on which artificial respiration had been kept up, became sooner cold than one killed and left undisturbed. The inference from these experiments, was, that instead of circulation and respiration maintaining heat, they dissipate it; and that as the heat is diminished by the destruction of the nervous centres, its disengagement must be ascribed to the action of those centres, and especially to that of the encephalon.

Thirty years ago, M. Chossat[1] endeavoured to discover the precise part of the nervous system that is engaged in calorification; but the results of his experiments were not such as to induce him to refer it exclusively, with Sir B. Brodie, to the encephalon. He divided the brain, anterior to the pons Varolii, in a living animal, so that the eighth nerve was uninjured. Respiration, consequently, continued, and inflation of the lungs was unnecessary. Notwithstanding this serious mutilation, the circulation went on; and M. Chossat observed distinctly, that arterial blood circulated in the arteries. Yet the temperature of the animal gradually sank, from 104° Fahr.,—its elevation at the commencement of the experiment,—to 76°, in twelve hours, when the animal died. It seemed manifest to M. Chossat, that, from the time the brain was divided, heat was no longer given off, and the body gradually cooled, as it would have done after death. He, moreover, noticed, that the time, at which the refrigeration occurred most rapidly was that in which the circulation was most active,—at the commencement of the experiment. In other experiments, M. Chossat paralysed the action of the brain by violent concussion, and injected a strong decoction of opium into the jugular vein,—keeping up artificial respiration. The results were the same. From these experiments, he drew the conclusion, that the brain has a direct influence over the production of heat.

His next experiments were directed to the discovery of the medium through which the brain acts,—the eighth pair of nerves, or spinal marrow. He divided the eighth pair in a dog, and kept up artificial respiration. The temperature sank gradually; and, at the expiration of sixty hours, when the animal died, it was reduced to 68° of Fahrenheit. Yet death did not occur from asphyxia or suspension of the phenomena of respiration; for the lungs crepitated; exhibited no signs of infiltration, and were partly filled with arterial blood. The animal appeared to M. Chossat to expire from cold. As, however, the mean depression of heat was less than in the preceding experiments, he inferred that a slight degree of heat is still disengaged after the section of the eighth pair; whilst, after injury done to the brain directly, heat is no longer given off. Again, he divided the spinal marrow beneath the occiput, and although artificial respiration was maintained, as in the experiments of Sir B. Brodie, the temperature gradually fell, and the animal

[1] Sur la Chaleur Animale, Paris, 1820, and Adelon, op. cit., iii. 416.

died ten hours afterwards, its heat being 79°; and as death occurred in this case so much more speedily than in the last, he inferred, that the influence of the brain over the production of heat is transmitted rather by the spinal marrow than by the eighth pair. In his farther experiments, M. Chossat discovered, when the spinal marrow was divided between each of the twelve dorsal vertebræ, that the depression of temperature occurred less and less rapidly, the lower the intervertebral section; and at the lowest was imperceptible: he, therefore, concluded, that the spinal marrow does not act directly in the function, but indirectly through the trisplanchnic nerve. To satisfy himself on this point, he opened the left side of a living animal, beneath the twelfth rib, and removed the left supra-renal capsule, dividing the trisplanchnic where it joins the semilunar plexus. The animal lost its heat gradually, and died ten hours afterwards in the same condition, as regarded temperature, as when the spinal marrow was divided beneath the occiput. Desiring to obtain more satisfactory results,—the last experiment applying to only one of the trisplanchnic nerves,—he tied the aorta, which supplies both, beneath the place where it passes through the arch of the diaphragm, at the same time preventing asphyxia by inflating the lungs. The animal lost its heat much more rapidly; and died in five hours. In all these cases, according to M. Chossat, death occurred from cold; the function, by which the caloric, constantly abstracted from the organism by the surrounding medium, is generated having been rendered impracticable. To obtain a medium of comparison, he killed several animals by protracted immersion in cold water, and found, that the lowest temperature to which the warm-blooded could be reduced, and life persist, was 79° of Fahrenheit. He also alludes to cases of natural death by congelation, which, he conceives, destroy in the manner before suggested,—that is, by impairing the nervous energy, as indicated by progressive stupor, and debility of the chief functions of the economy. Lastly:—on killing animals suddenly, and attending to the progress of refrigeration after death, he found it to be identical with that which follows direct injury of the brain, or the division of the spinal marrow beneath the occiput. A view somewhat analogous to this of M. Chossat, was embraced by Sir Everard Home.[1] He considered, that the phenomenon is restricted to the ganglionic part of the nervous system; resting his opinion chiefly on the circumstance, that there are animals, which have a brain, or some part equivalent to one, and whose temperature is not higher than that of the surrounding medium; whilst all the animals that evolve heat are provided with nervous ganglia.

The doctrines of Brodie, Chossat, and Home have been considered by the generality of the chemists—by Brande,[2] Thomson,[3] and Paris,[4] —to be completely subversive of the chemical view, which refers the production of animal heat to respiration; and their position,—that it is a nervous function,—has seemed to be confirmed by the facts at-

[1] Philos. Trans., p. 257, for 1825; Journal of Science and Arts, xx. 307; and Lect. on Comparative Anat., v. 121 and 194, Lond., 1828.

[2] Manual of Chemistry, vol. iii.

[3] System of Chemistry, vol. iv.

[4] Medical Chemistry, p. 327, Lond., 1825.

tendant upon injury done to the nerves of parts, and by what is witnessed in paralytic limbs, the heat of which is generally and markedly inferior to that of the sound. But there are many difficulties in the way of admitting, that the nervous system is the special organ for the production of animal temperature. Dr. Wilson Philip,[1] from a repetition of the experiments of Sir Benjamin Brodie, was led to conclude, that the cause of the temperature of the body diminishing more rapidly, when artificial inflation was practised, than when the animal was left undisturbed, was—too large a quantity of air having been sent into the lungs; for he found, when a less quantity was used, that the cooling process was sensibly retarded by the inflation. The experiments of Legallois,[2] Hastings,[3] and Williams,[4] although differing from each other in certain particulars, corroborate the conclusion of Dr. Philip; and, what is singular, appear to show, that the temperature occasionally *rises* during the experiment; a circumstance which tends rather to confirm the view, that respiration is concerned materially in the evolution of heat.

Many of the facts detailed by M. Chossat are curious, and exhibit the indirect agency of the nervous system; but his conclusion, that the trisplanchnic is the great organ for its developement, is liable to the objections already brought against the theory, which looks upon the heart, or the lung, as a furnace for the disengagement of caloric,—that they ought to be consumed in a short space of time. All the facts, however, clearly show, that, in the upper classes of animals, the three great acts of innervation, respiration, and circulation are indirectly concerned in the function; but not that any one of them is the special seat. M. Edwards has maintained, that it is more connected with the second of these than with either of the others. Thus, animals, he argues, whose temperature is highest, bear privation of air least: cold-blooded animals suffer comparatively little; and young animals are less affected than the adult. Now, the greater the temperature of the animal, and the nearer the adult age, the greater is the consumption of oxygen. He farther observed, that whilst season modifies calorification, it affects also respiration; and if, in summer, less heat be elicited, and in winter more, it is found that respiration consumes less oxygen in the former than in the latter season.

The experiments of M. Legallois, as well as those instituted by M. Edwards, led the latter to infer, that there is a certain ratio between heat and respiration in both cold-blooded and warm-blooded animals, and in hibernating animals both in the periods of torpidity and full activity. When the eighth pair of nerves is divided in the young of the mammalia, a considerable diminution is produced in the opening of the glottis; so that, in puppies recently born, or one or two days old, so little air enters the lungs, that when the experiment is made under ordinary circumstances the animal perishes as quickly as if it were

[1] An Experimental Inquiry into the Laws of the Vital Functions, 3d edit., p. 180.
[2] Annales de Chimie, iv. 5, Paris, 1817.
[3] Wilson Philip, op. cit.; and Journal of Science, &c., xiv. 96.
[4] Edinb. Medico-Chirurgical Transact., ii. 192.

entirely deprived of air. It lives about half an hour. But, if the same operation be performed upon puppies of the same age benumbed with cold, they live a whole day. In the first case M. Edwards thinks, and plausibly, the small quantity of air is insufficient to counteract the effect of the heat, whilst, in the other, it is sufficient to prolong life considerably; and he draws the following practical inferences applicable to the adult age, and particularly to man. A person is asphyxied by an excessive quantity of carbonic acid in the air he breathes; the pulse is no longer perceptible; the respiratory movements cannot be discerned, but his temperature is still elevated. How should we proceed to recall life? Although the action of the respiratory organs is no longer perceptible, all communication with the air is not cut off. It is in contact with the skin, on which it exerts a vivifying influence: it is also in contact with the lungs, in which it is renewed by the agitation constantly taking place in the atmosphere, and by the heat of the body, which rarefies it. The heart continues to beat, and a certain degree of circulation is kept up, although not perceptible by the pulse. The temperature of the body is too high to allow the feeble respiration to produce upon the system all the effect of which it is capable. The temperature must, therefore, be reduced; the patient withdrawn from the deleterious atmosphere; be stripped of his clothes, in order that the air may have a more extended action upon his skin; be exposed to the cold, although it be winter, and cold water be thrown upon his face until the respiratory movements reappear. This is precisely the treatment adopted to revive an individual from a state of asphyxia. If, instead of cold, continued warmth were to be applied, it would be one of the most effectual means of extinguishing life,—a consequence, which like the former, is confirmed by experience. In sudden faintings, when the pulse is weak or imperceptible, the action of the respiratory organs diminished, and sensation and voluntary motion suspended, persons, the most ignorant of medicine, are aware, that means of refrigeration must be employed,—such as exposure to air, ventilation, and sprinkling with cold water. In violent attacks of asthma, also, when the extent of respiration is so limited that the patient experiences a sense of suffocation, he courts the cold air even in the severest weather; opens the windows; breathes a frosty air, and finds himself relieved.

As a general rule, an elevated temperature accelerates the respiratory movements, but the degree of temperature requisite to produce this effect is not the same in all persons. The object of the accelerated respiration is, that more air may come in contact with the lungs in a given time, so as to reanimate what the heat depresses. It is proper to remark, however, that we meet with many exceptions to the rule endeavoured to be laid down by M. Edwards, as regards the constant ratio between heat and respiration. Experiments on the lower animals, and pathological cases in man, have shown, that lesions of the upper part of the spinal marrow give occasion, at times, to an extraordinary developement of heat. In the case of a man at St. George's Hospital, London, labouring under a lesion of the cervical vertebræ, Sir B. Brodie observed the temperature to rise to 111°, at a time when

the respirations were not more than five or six in a minute.[1] Drs. Graves and Stokes[2] give the case of a patient who laboured under very extensive developement of tubercles, had tubercular abscesses in the upper portions of both lungs, and general bronchitis. In this case, at a period when the skin was hotter than usual, and the pulse 126, the respirations were only 14 in a minute. Besides, as Dr. Alison[3] has remarked, the temperature of the body is not raised by voluntarily increasing or quickening the acts of respiration, but by voluntary exertions of other muscles, which accelerate the circulation, and thus necessitate an increased frequency of respiration;—a fact, which would seem to show that calorification is dependent not simply on the application of oxygen to the blood, but on the changes that take place during the circulation, and to the maintenance of which its oxygenation is one essential condition. Moreover, in the fœtus in utero, there is, of course, no respiration; yet its temperature equals, and indeed is said to even exceed, that of the mother; and we know that its circulation is more rapid, and its nutrition more active.[4]

That innervation is indirectly concerned in the phenomenon is proved by the various facts, which have been referred to; and Legallois, although he does not accord with Sir B. Brodie, conceives that the temperature of the body is greatly under the influence of the nervous system, and that whatever weakens the nervous power, proportionally diminishes the capability of producing heat. Dr. Philip, too, concluded from his experiments, that the nervous influence is so intimately connected with the power of evolving heat, that it must be looked upon as a necessary medium between the different steps of the operation. He found, that if the galvanic influence be applied to fresh-drawn arterial blood, an evolution of heat, amounting to three or four degrees, takes place; at the same time, the blood assumes the venous hue, and becomes partly coagulated. He regards the process of calorification as a secretion; and explains it upon his general principle of the identity of the nervous and galvanic influences, and the necessity for the exercise of such influence in the function of secretion.

Mr. H. Earle[5] found the temperature of paralysed limbs slightly lower than that of sound limbs, and the same effect is observed to supervene on traumatic injuries of the nerves. In a case of hemiplegia, of five months' duration, under the author's care at the Blockley Hospital, the thermometer in the right—the sound—axilla of the man stood at $96\frac{1}{2}°$; in the axilla of the paralysed side, at 96°. The difference in temperature of the hands was more marked—that of the right being 87°, whilst that of the left was only $79\frac{1}{2}°$. In another case—that of a female—of two weeks' duration, accompanied with signs of cerebral

[1] London Medical Gazette for June, 1836.

[2] Dublin Hospital Reports, vol. v.; and Dr. Graves, Clinical Lectures, American Med. Lib. edit., p. 126, Philad., 1838.

[3] Outlines of Physiology, Lond., 1831.

[4] On the connexion of respiration with calorification, see P. H. Bérard, art. Chaleur Animale, in Dict. de Méd., 2de édit., vii. 175, Paris, 1834; and Mr. Newport on the Temperature of Insects, and its Connexion with the Functions of Respiration and Circulation in this Class of Invertebrated Animals, Philos. Transact., part ii. 4to. p. 77, Lond., 1837.

[5] Medico Chirurgical Transactions, vii. 173, Lond., 1819.

turgescence, the temperature in the axilla of the sound side was 100°; in that of the paralysed 98·25°: of the hand of the sound side, 94°; of the other, 90°. It is a general fact, that the temperature of the paralysed side in hemiplegia is less than that of the sound; yet the irregularity of nervous action is so great, and the power of resistance to excitant or depressing agents so much diminished, that the author has not unfrequently found it more elevated.[1] In such cases, moreover, the nutrition of the limb will fall off, in consequence of the want of exercise; and this circumstance would sufficiently account for any diminution of temperature that might be manifested.

Lastly, that the circulation is necessary to calorification, we have evidence in the circumstance, that if the vessels proceeding to a part be tied, animal heat is no longer disengaged from it. It has been seen, however, that there is no certain ratio between the heat and frequency of the pulse.

It is manifest, then, that in animals, and especially in the warm-blooded, the three great vital operations are necessary for the disengagement of the due temperature, but we have no sufficient evidence of the direct agency of any one; whilst we see heat elicited in the vegetable, in which these functions are at all events rudimental; and the existence of one of them—innervation—more than doubtful.

The views of those who consider, that the disengagement of caloric occurs in the intermediate system or system of nutrition of the whole body, appear to be most consistent with observed phenomena. These have varied according to the physical circumstances, that have been looked upon as producing heat. By some, it was regarded as the product of an effervescence of the blood and humours; by others, as owing to the disengagement of an igneous matter or spirit from the blood; by others ascribed to an agitation of the sulphureous parts of the blood; whilst Boerhaave[2] and Douglas[3] ascribed it to the friction of the blood against the parietes of the vessels, and of the corpuscles against each other.

In favour of the last hypothesis, it was urged, that animal heat is in a direct ratio with the velocity of the circulation, the circumference of the vessels, and the extent of their surface; and that we are thus able to explain, why the heat of parts decreases in a direct ratio with their distance from the heart; whilst the greater heat of the arterial blood in the lungs was accounted for by the supposition, that the pulmonary circulation is far more rapid. Most of these notions—it need scarcely be said—were entirely hypothetical. The data were generally incorrect, and the deductions characteristic of the faulty physics of the period in which they were hazarded. The correct view, it appears to us, is, that caloric is disengaged in every part, by a special chemico-vital action, which, in animals, is greatly under the nervous influence. In this manner, calorification becomes a function executed in the whole system of nutrition; and, therefore, appropriately

[1] American Med. Intelligencer, Oct. 15, 1838, p. 252.
[2] Van Swieten, Comment. in Boerhaav. Aphorism., &c., §§ 382, 675, Lugd. Bat., 1742–1772.
[3] On Animal Heat, p. 47, Lond., 1747.

considered in this place. It has been remarked by Tiedemann,[1] that the intussusception of alimentary matters, and their assimilation by digestion and respiration; the circulation of the humours; nutrition and secretion; the renewal of materials accompanying the exercise of life, and the constant changes of composition in the solid and liquid parts of the organism,—all of which are influenced by the nervous system,—participate in the evolution of heat, and we deceive ourselves, when we look for the cause in one of those acts only. In certain experiments by Dr. Robert E. Rogers,[2] of the University of Virginia, he found that when recently drawn venous blood contained in a freshly removed pig's bladder was immersed in oxygen gas, there was a remarkable elevation of temperature. Dr. Davy[3] performed experiments which led to the same results. In one of these, he took a very thin vial, of the capacity of eight fluidounces, and carefully enveloped it in badly conducting substances,—for example, in several folds of flannel, fine oiled paper, and oiled cloth. Thus prepared, and a perforated cork being provided holding a delicate thermometer, two cubic inches of mercury were introduced, and immediately after it was filled with venous blood kept liquid by agitation. The vial was then corked, and shaken. The thermometer included was stationary at 45°. After five minutes, during which it remained so, it was withdrawn; the vial, closed by another cork, was transferred inverted to a mercurial bath, and $1\frac{1}{2}$ cubic inch of oxygen introduced. The common cork was returned, and the vial was well agitated for about a minute; the thermometer was now introduced; it rose immediately to 46°, and by continuing the agitation, to 46·5°, and very nearly 47°. This experiment was made on the blood of the sheep. These, and other experiments of a similar character, Dr. Davy thinks, appear to favour the idea, that animal heat is owing, first, to the fixation or condensation of oxygen in the blood of the lungs in its conversion from venous to arterial; and secondly, to the combinations into which it enters in the circulation in connexion with the different secretions and changes essential to animal life.

More recent experiments by M. Chossat,[4] confirm the view of the great dependence of calorification on the proper supply of materials on which changes have to be effected in the system of nutrition. He found, that birds, totally deprived of food and drink, experienced a gradual, although slight daily diminution of temperature. This was not shown so much by a fall of their maximum heat, as by an increase in the diurnal variation which existed in the healthy state. The amount of this variation in birds properly supplied with food is $1\frac{1}{2}$° of Fahrenheit daily—the maximum being about noon, and the minimum at midnight. In the state of inanition, however, the average variation was about 6°, and it increased as the animal became weaker. The

[1] Traité de Physiologie, &c., trad. par. Jourdan, p. 514, Paris, 1831.

[2] Amer. Journal of the Med. Sciences, p. 297, for Aug., 1836.

[3] Proceedings of the Royal Society for 1837–8, No. 34, and Researches Physiological and Anatomical, American Med. Lib. edit., p. 89, Philad., 1840.

[4] Recherches Expérimentales sur l'Inanition, Paris, 1843; noticed in Brit. and For. Med. Rev., April, 1844.

gradual rise of temperature, too, which should have taken place between midnight and noon, was retarded; whilst the fall subsequent to noon commenced much earlier than in the healthy state; so that the average of the whole day was lowered by about 4½° between the first and last day but one of this condition. On the last day, the diminution took place very rapidly, and the thermometer fell from hour to hour, until death supervened—the whole loss on that day being about 25° Fahrenheit, making the total depression about 29½°. On examining the amount of loss sustained by the different organs of the body, it was found that 93 per cent. of the fat had disappeared,—all, in fact, that could be removed; whilst the nervous centres exhibited scarcely any diminution in weight. The loss in the weight of the whole body averaged about 40 per cent. This preservation of weight on the part of the nervous centres has been regarded, but with little plausibility, to favour the idea, that they may be formed from fatty matter,[1]—a portion of the fat absorbed being appropriated for their nutrition; yet it would be strange, if proteinaceous compounds should be required for other organized structures, and the highest of all in importance should originate from a non-nitrogenized material, or what Liebig terms an "element of respiration." Dr. Carpenter,—in commenting on the experiments of Chossat—remarks, that from the constant coincidence between the entire consumption of the fat, and the depression of temperature, joined to the fact that the duration of life under the inanitiating process evidently varied *cæteris paribus* with the amount of fat previously accumulated in the body, the inference seems irresistible, that the calorifying power depended chiefly—if not wholly—on the materials supplied by this substance; and he adds—whenever the store of combustible matter in the system was exhausted, whether by the respiratory process alone, or by this in conjunction with the conversion of adipous matter into the materials for the nervous or other tissues, the inanitiated animals died by the cooling of their bodies consequent upon the loss of calorifying power. This is plausible; yet it can be readily imagined, that the loss of the accustomed supply of aliment may so interfere with changes perpetually taking place in the system of nutrition, as to give occasion to the functional changes, which eventuate in the loss of life, and that the system cannot exist for any length of time on the materials that are taken up from itself. The use of the fat as a nutriment deposited for special occasions is generally admitted by physiologists. Its use as an element of respiration has only been suggested of late years; and it must be admitted, that the view which has been embraced by Dr. Carpenter is confirmed by the experiments of M. Chossat, who found that if inanitiated animals, when death is impending, were subjected to artificial heat, they were almost uniformly restored from a state of insensibility and want of muscular power to a condition of comparative activity; their temperature rose; muscular power returned; they flew about the room and took food when it was presented to them; and if the artificial assistance was sufficiently prolonged, and they were not again subjected to the starving process, most of

[1] Carpenter, Principles of Human Physiology, 2d edit., p. 675, London, 1844.

them recovered. In other words, it might be said, that the application of artificial warmth prevented the farther consumption of the fuel —fat—and exerted a most salutary agency on the organic as well as the animal functions.

The experiments of M. Chossat are the more worthy of attention and of careful repetition, from their seeming to lead to a conclusion, which, Dr. Carpenter thinks, can scarcely be questioned, from the similarity of the phenomena,—that inanitiation with its consequent depression of temperature is the immediate cause of death in various diseases of exhaustion. Hence it has been suggested, that in those forms of febrile maladies in which no decided lesion is discoverable after death, a judicious and timely application of artificial heat might prolong life until the malignant influence—as in cases of narcotic poisoning—had passed away. It has been suggested, too, that the beneficial result of alcohol in protracted cases of such fevers, and the large amount in which it may be given with impunity, may probably be accounted for on this principle. "We cannot support the system in fever by *aliment*, for this would not be digested, even if it were taken into the stomach. But we well know the beneficial effects of alcohol in its advanced stages; and the large quantity of this stimulus that may be administered in many cases of fever is a matter of familiar experience. Now, admitting that its beneficial operation is partly due to its specific effect upon the nervous system, we cannot help thinking, that we are to regard it as also resulting from the new supply of combustible material, which is thus introduced in the only form in which it can be taken up by the vascular system. If we turn our attention for a moment to the state of the digestive apparatus at this period, we shall at once see why no other substance should answer the same purpose. In the advanced stage of fever, the secretion of gastric fluid, and the special absorbent process which takes place through the villi and lacteals, seem to be in complete abeyance. Still, however, simple imbibition may go on through the walls of the bloodvessels, provided that the circumstances are favourable to the production of endosmose; that is, provided the fluid in the alimentary canal is less dense than the blood. Now, the substances on which we ordinarily depend for the support of the respiratory process are either of an oily, a saccharine, or a mucilaginous character. Oily substances cannot be taken in by imbibition, since they completely check the endosmotic current. Saccharine and mucilaginous substances can only be taken in, when their solution is so dilute as to be of a density much inferior to that of the blood; hence they must be given in a large bulk of fluid; a practice of which experience has shown the benefit. But alcohol, being already of a density far inferior to that of the blood, is easily absorbed; and, from deficiency of other materials, it is rapidly consumed, so that a very large quantity may be thus ingested, without its stimulating effects being perceptible; just as we see that, in a very cold atmosphere, large quantities of spirituous liquors may be taken with impunity, on account of the rapid combustion they undergo."[1]

It is by the theory of the general evolution of caloric in the capillary

[1] Brit. and For. Med. Rev., April, 1844, p. 356.

system, or in the system of nutrition, that we are able to account for the increased heat that occurs in certain local affections, in which the temperature greatly exceeds that of the same parts in health. By some, it has been doubted, whether, in local inflammation, any such augmentation of temperature exists; but the error seems to have arisen from the temperature of the part in health having been generally ranked at blood heat; whereas it differs essentially in different parts. Dr. Thomson found, that a small inflamed spot in his right groin gave out, in the course of four days, a quantity of heat sufficient to have heated seven wine-pints of water from 40° to 212°; yet the temperature was not sensibly less than that of the rest of the body at the end of the experiment, when the inflammation had ceased.[1] By supposing, too, that calorification is effected in every part of the body, we can understand why different portions should have different temperatures; as the activity of the function may vary, in this respect, according to the organ. MM. Chopart and Dessault found the heat of the rectum 100°; of the axilla and groin, when covered with clothes, 96°; and of the chest, 92°. Dr. Davy[2] found the temperature of a naked man, just risen from bed, to be 90° in the middle of the sole of the foot; 93° between the inner ankle and tendo achillis; 91·5° in the middle of the shin; 93° in the calf; 95° in the ham; 91° in the middle of the thigh; 96·5° in the fold of the groin; 95° at three lines beneath the umbilicus; 94° on the sixth rib of the left side; 93° on the same rib of the right side; and 98° in the axilla. MM. Edwards and Gentil found the temperature of a strong adult male in the rectum and mouth, 102°; in the hands, 100°; in the axilla and groins, 98°; on the cheeks, 97°; on the prepuce and feet, 96°; and on the chest and abdomen, 95°. It is obvious, however, that all these experiments concern only the temperature of parts, which can be readily modified by the circumambient medium. To judge of the comparative temperature of the internal organs, Dr. Davy killed a calf, and noted that of different parts, both external and internal. The blood of the jugular vein raised the thermometer to 105·5°; that of the carotid artery to 107°. The heat of the rectum was 105·5°; of the metatarsus, 97°; of the tarsus, 90°; of the knee, 102°; of the head of the femur, 103°; of the groin, 104°; of the under part of the liver, 106°; of the substance of that organ, 106°; of the lung, 106·5°; of the left ventricle, 107°; of the right, 106°; and of the substance of the brain, 104°. In the case of fistulous opening into the stomach, observed by Dr. Beaumont,[3] the thermometer indicated a difference of three-fourths of a degree between the heat of the splenic and pyloric orifices of the stomach; the temperature of the latter being more elevated. It is not easy to account for these differences, without supposing, that each part has the power of disengaging its own heat, and that the communication of caloric from one part to another, is not sufficiently ready to prevent the difference from being perceptible.

Of the mode in which heat is evolved in the system of nutrition, it is impossible for us to arrive at any satisfactory information. The

[1] Annals of Philosophy, ii. 27.
[2] Philosoph. Transact. for 1814.
[3] Exp. and Observations on the Gastric Juice, p. 274, Plattsburg, 1833.

result alone indicates, that the process has been accomplished. In the present state of our knowledge, we are compelled to refer it to some chemico-vital action, of the nature of which we are ignorant; but which seems to be possessed by all organized bodies,—vegetable as well as animal. We know that wherever carbon unites with oxygen to form carbonic acid; oxygen with hydrogen to form water; or with phosphorus or sulphur to form phosphoric acid, and sulphuric acid, as is constantly the case in organized bodies, heat must be disengaged. We shall have to refer hereafter, when treating of the phenomena of DEATH, to interesting observations of Dr. Dowler of New Orleans, and others, showing, that the heat of the body may rise after somatic death,—that is, after the cessation of circulation and respiration; and that the elevation of temperature varies materially in different parts of the body. The disengagement of caloric, which takes place until the supervention of the putrefactive process, must manifestly be of a physical character, and of course in no respect connected with respiration. Still, it may admit of a question, whether it be identical with that which takes place in the living body, and constitutes the function now under consideration. This much, however, the observations establish, that physical changes in the recently dead may give occasion to the evolution of heat in a manner strikingly analogous to what takes place during life.

It was stated early in this section, that man possesses the power of resisting cold as well as heat within certain limits, and of preserving his temperature greatly unmodified. A few remarks are needed in regard to the direct and indirect agents of these counteracting influences. As the mean temperature of the warmest regions does not exceed 85° of Fahrenheit, it is obvious that he must be constantly giving off caloric to the surrounding medium;—still, his temperature remains the same. This is effected by the mysterious agency which we have been considering, materially aided, however, by several circumstances, both intrinsic and extrinsic. The external envelope of the body is a bad conductor of caloric, and therefore protects the internal organs, to a certain extent, from the sudden influence of excessive heat or cold. But the cutaneous system of man is a much less efficient protection than that of animals. In the warm-blooded in general, the bodies are covered with hair or feathers. The whale is destitute of hair; but, besides the protection, which is afforded by the extraordinary thickness of the skin, and the stratum of fat—a bad conductor of caloric—with which the skin is lined, as the animal constantly resides in the water, it is not subjected to the same vicissitudes of temperature as land animals. Seals, bears, and walruses, which seek their food in the colder seas, sleep on land. They have a coating of hair to protect them. In the case of certain of the birds of the genus *Anas*, of northern regions, we meet with a singular anomaly,—the whole of the circumference of the anus being devoid of feathers; but, to make amends for this deficiency, the animal has the power of secreting an oleaginous substance, with which the surface is kept constantly smeared. It may be remarked, that we do not find the quantity of feathers on the bodies of birds to be proportionate to the cold of the climates in which they reside, as is pretty universally the case regarding the quantity of hair on the mammalia.

Man is compelled to have recourse to clothing for the purpose of preventing the sudden abstraction or reception of heat. This he does by covering himself with substances that are bad conductors of caloric, and retain an atmosphere next to the surface, which is warmed by the caloric of the body. He is compelled, also, in the colder seasons, to have recourse to artificial temperature; and it will be obvious, from what has been said, that the greater the degree of activity of any organ or set of organs, the greater will be the heat developed: and in this way muscular exertion and digestion must influence its production. By an attention to all these points, and by his acquaintance with the physical laws relative to the developement and propagation of caloric, man is enabled to live amongst the Arctic snows, as well as in climates where the temperature is frequently, for a length of time, upwards of 150° lower than that of his own body. The contrivances adopted in the polar voyages, under the direction of Captain Parry and others, are monuments of ingenuity directed to obviate one of the greatest obstacles to prolonged existence in cold inhospitable regions, for which man is naturally incapacitated, and for which he attains the capability solely by the exercise of that superior intellect with which he has been vested by the Author of his being. In periods of intense cold, the extreme parts of the body, unless carefully protected, do not possess the necessary degree of vital action to resist congelation. In the disastrous expedition of Napoleon to Russia, the loss of the nose and ears was a common casualty; and, in Arctic voyages, frost-bites occur in spite of every care.[1] When the temperature of the whole body sinks to about 78° or 79°, death takes place, preceded by the symptoms of nervous depression, which have been previously detailed.

The counteracting influence exerted, when the body is exposed to a temperature greatly above the ordinary standard of the animal, is as difficult of appreciation as that by which calorification is effected. The probability is, that in such case the disengagement of heat is suspended; and that the body receives it from without by direct, but not by rapid, communication, owing to its being an imperfect conductor of caloric. Through the agency of this extraneons heat, the temperature rises a limited number of degrees; but its elevation is generally considered to be checked by the evaporation constantly taking place through the cutaneous and pulmonary transpirations. For this last idea we are indebted to Dr. Franklin,[2] and its correctness and truth have been maintained by most observers. MM. Berger and Delaroche put into an oven, heated to from 120° to 140°, a frog, and one of those porous vessels called *alcarazas*—which permit the transudation of the fluid, within them, through their sides—filled with water at the temperature of the animal, and two sponges, imbibed with the same water. The temperature of the frog at the expiration of two hours, was 99°; and the other bodies continued at the same. Having substituted a rabbit for the frog, the result was identical. On the other hand, having placed animals in a warm atmosphere, so saturated with humidity that

[1] Larrey, Mémoires de Chirurgie Militaire et Campagnes, tom. iv. p. 91, 106, and 123, Paris, 1817.

[2] Works, iii. 294, Philad., 1809; or Sparks's edit., vi. 213, Boston, 1838.

no evaporation could occur, they received the caloric by communication, and their temperature rose; whilst inert, evaporable bodies, put into a dry stove, became but slightly warmed;—much less so, indeed, than the warm-blooded animals in the moist stove. Hence, they concluded, that evaporation is a great refrigerative agent when the body is exposed to excessive heat; and that such evaporation is considerable is shown by the loss in weight which animals sustain by the experiment. It has been contested, however, that the cutaneous evaporation has any effect in tempering the heat of the body; whilst it is admitted that the elimination from the system of a certain quantity of aqueous matter is all important, and that whatever arrests it is the source of morbid phenomena. MM. Becquerel and Breschet[1] found, when the hair of rabbits had been shaved off, and the skin covered with an impermeable coating of strong glue, suet, and resin, that the animals died soon afterwards; and, they thought, by a process of asphyxia in consequence of the transpiration from the skin being prevented. In these experiments, to their surprise, the temperature of the animals, instead of rising, fell considerably. Thus, the temperature of the first rabbit, before it was shaved and covered with the impermeable coating, was 38° Centigrade; but immediately after the coating was dry, the temperature of the muscles of the thigh and breast had fallen to 24·5° Centigrade. In another rabbit, on which the coating was put on with more care,—as soon as it was dried, the temperature was found to have fallen so much that it was only three degrees above that of the surrounding atmosphere, which was, on that day, 17° Centigrade. An hour after the animal died. These experiments—and they have been repeated with like results by M. Magendie[2]—clearly exhibit the importance of the functions executed by the skin. Dr. Carpenter[3] thinks they place in a very striking point of view the importance of the cutaneous surface as a respiratory organ, and enable us to understand how, when the aerating power of the lungs is nearly destroyed by disease, the heat of the body is kept up to its natural standard by the action of the skin. "A valuable therapeutical indication, also," he adds, "is derivable from the knowledge which we thus gain of the importance of the cutaneous respiration; for it leads us to perceive the desirableness of keeping the skin moist in those febrile diseases in which there is great heat and dryness of the surface, since aeration cannot properly take place through a dry membrane."

M. Edwards, in his experiments on the influence of physical agents on life, observed, that warm-blooded animals have less power of producing heat, after they have been exposed for some time to an elevated temperature, as in summer; whilst the opposite effect occurs in winter. He instituted a series of experiments, which consisted in exposing birds to the influence of a freezing mixture, first in February, and afterwards in July and August; and observing in what degree they were cooled by remaining in this situation for equal lengths of time; the result was, that the same kind of animal was cooled six or eight times as much in

[1] Comptes Rendus, Oct., 1841.
[2] Gazette Médicale de Paris, 6 Dec., 1843.
[3] Human Physiology, § 726, Lond., 1842.

the summer as in the winter months. This principle he presumes to be of great importance in maintaining the regularity of the temperature at different seasons; even more so than evaporation, the effect of which, in this respect, he thinks, has been greatly exaggerated. From several experiments on yellow-hammers, made at different periods in the course of the year, it would result, that the averages of their temperature ranged progressively upwards from the depth of winter to the height of summer, within the limits of five or six degrees of Fahrenheit; and the contrary was observed in the fall of the year. Hence, M. Edwards infers, and with probability, that the temperature of man experiences a similar fluctuation.[1]

When exposed to high atmospheric temperature, the ingenuity of man has to be as much exerted as under opposite circumstances. The clothing must be duly regulated according to physical principles,[2] and perfect quietude be observed, so that undue activity of any of the organs, that materially influence the disengagement of animal heat, may be prevented. It is only within limits, that this refrigerating action is sufficient. At a certain degree, the transpiration is inadequate; the temperature of the animal rises, and death supervenes.

CHAPTER VII.

SECRETION.

We have next to describe an important and multiple function, which also takes place in the intermediate system—in the very tissue of our organs—and separates from the blood the various humours. This is the function of *secretion*,—a term literally signifying *separation*—and which has been applied both to operation and product. Thus, the liver is said to separate the bile from the blood by an action of secretion, and the bile is said to be a secretion.

The organs that execute the various secretory operations differ greatly from each other. They have, however, been grouped by anatomists into three classes, each of which will require a general notice.

1. ANATOMY OF THE SECRETORY APPARATUS.

The secretory organs have been divided into the *exhalant*, *follicular*, and *glandular*.

The remarks made respecting the *exhalant vessels* under the head of Nutrition will render it unnecessary to allude, in this place, to any of the apocryphal descriptions of them, especially as their very existence is supposititious. Many, indeed, imagine them to be nothing more than the minute radicles of ordinary arteries.

The *follicle* or *crypt* has the form of an ampulla or vesicle, and is situate in the substance of the skin and mucous membranes; secreting a fluid for the purpose of lubricating them. In the exhalant vessel,

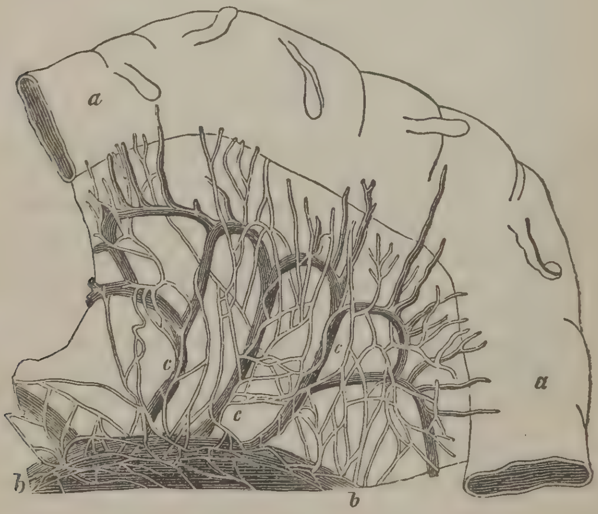
[1] De l'Influence des Agens Physiques, p. 489; and Hodgkin's and Fisher's translation, Lond., 1832.

[2] See the chapter on Clothing in the author's Human Health, p. 340, Philadelphia, 1844.

the secreted fluid passes immediately from the bloodvessel, without being received into any excretory duct; and, in the simplest follicle, there is essentially no duct specially destined for the excretion of the humour. It is membranous and vascular, having an internal cavity into which the secretion is poured; and the product is excreted upon the surface beneath which it is situate, either by a central aperture, or by a very short duct—if duct it can be called—generally termed a *lacuna*. Many of the so called follicles are, however, more complicated, and consist, like the Meibomian, of various *cul-de-sacs*, with separate ducts which open into one; so that the distinction between a compound follicle and a gland is not easily made; and physiologically no difference can be considered to exist.

The *gland* is of a more complex structure than the last. It consists of an artery which conveys blood to it; of an intermediate body,—the *gland*, properly so called,—and of an excretory duct to carry off the secreted fluid, and to pour it on the surface of the skin or mucous membrane. The bloodvessel, that conveys to the gland the material from which the secretion has to be effected, enters the organ,—at times,

Fig. 315.



Secreting Arteries, and Nerves of Intestines.

a, a. A portion of intestine. *b, b*. Part of aorta. *c, c, c*. Nerves following branches of aorta to supply intestine.

by various branches; at others, by a single trunk; and ramifies in the tissue of the gland; communicating at its extremities with the origins of the veins and excretory ducts. These ducts arise by fine radicles at the part where the arterial ramifications terminate; and they unite to form larger and less numerous canals, until they end in one large duct, as in the pancreas; or in several, as in the lachrymal gland,—the duct generally leaving the gland at the part where the bloodvessel enters. Of this we have a good exemplification in the kidney.

The pavement and the cylinder epithelium, as well as all the intermediate forms, are met with in the different glands. These are not necessarily a continuation of the epithelium of the cutaneous system; on the contrary, that of the latter is often seen changing its form at its entrance into the gland.

Besides the vessels above mentioned, veins exist, which communicate with the bloodvessels that convey blood to the gland, both for the formation of the humour and the nutrition of the organ; and which return the residuary blood to the heart. Lymphatic vessels are likewise there; and nerves,—proceeding from the ganglionic system,—form a net-work around the secreting arteries, as in Fig. 315, accompany them into the interior of the organ, and terminate, like them, invisibly. Bordeu[1] was of opinion, that the glands, judging from the parotid, are largely supplied with nerves. They do not, however, all belong to it, some merely crossing it in their course to other parts. Bichat,[2] from the small number sent to the liver, was induced to draw opposite conclusions to those of Bordeu.

These may be looked upon as the great components of the glandular structure. They are bound together by areolar tissue, and have generally an outer envelope. The intimate texture of these organs has been a topic of much speculation. It is generally considered, that the final ramifications of the arterial vessels, with the radicles of the veins and excretory ducts, and the final ramifications of the lymphatic vessels and nerves, form so many small lobules, composed of minute, granular masses. Such, indeed is the appearance the texture presents when examined by the naked eye. Each lobule is conceived to contain a final ramification of the vessel or vessels that convey blood to the organ, a nerve, a vein, a lymphatic, and an excretory duct,—with areolar tissue binding them together. When the organ has an external membrane, it usually forms a sheath to the various vessels. The lobated structure is not equally apparent in all the glands. It is well seen in the pancreas, salivary and lachrymal. The precise mode in which the vessel, from the blood of which the secretion is effected, communicates with the excretory duct, does not admit of detection. Professor Müller[3] maintains, that the glandular structure consists essentially of a duct with a blind extremity, on whose parietes plexuses of bloodvessels ramify, from which the secretions are immediately made,—a view which was confirmed by the pathological appearances, in a case of disease of the portal system that fell under the author's observation, and is referred to hereafter. The opinion of Malpighi[4] was similar. He affirmed that such glands as the liver are composed of very minute bodies, called *acini* from their resemblance to the stones of grapes;—that these acini are hollow internally, and covered externally by a network of bloodvessels; and that these minute bloodvessels pour into the cavities of the acini the secreted fluid, from which it is subsequently taken up by

[1] Sur les Glandes, in Œuvres Complètes, par M. Richerand, Paris, 1818.

[2] Anat. Général., tom. ii.

[3] De Glandular. Secernent. Structurâ Penitiori, &c., Lips., 1830; or the English edit. by Mr. Solly, Lond., 1839.

[4] Opera Omnia, &c., p. 300, Lugd. Batav., 1687.

the excretory ducts. Ruysch,[1] however, held, that the acini of Malpighi are merely convoluted vessels, continuous with the excretory ducts. In Malpighi's view, the secretory organ is a mere collection of follicles; in Ruysch's, simply an exhalant membrane, variously convoluted. "The chief, if not the only difference," says a popular writer,[2] "between the secreting structure of glands and that of simple surfaces, appears to consist in the different number and the different arrangement of their capillary vessels. The actual secreting organ is in both cases the same,—capillary bloodvessel; and it is uncertain whether either its peculiar arrangement, or greater extent in glandular texture, be productive of any other effect than that of furnishing the largest quantity of bloodvessels within the smallest space. Thus convoluted and packed up, secreting organ may be procured to any amount that may be required, without the inconvenience of bulk and weight."

It is manifest, that the simplest form of the secretory apparatus consists of simple capillary vessel, and animal membrane; and that the follicles and glands are structures of a more complex organization, but still essentially identical;—all perhaps—as will be seen presently—executing their functions by means of cell agency. Or, to use the views and language of the day, every secreting organ possesses as essential parts of its structure, a simple and apparently anhistous or textureless membrane, called *primary* or *basement membrane; cells* and *bloodvessels:* and by some, all the various modes in which these three structural elements are arranged have been classed under one or other of two principal divisions—*membranes*, and *glands*.[3]

Fig. 316.

Plan of a Secreting Membrane.

a. Membrana propria or basement membrane. *b*. Epithelium, composed of secreting nucleated cells. *c*. Layer of capillary bloodvessels.

Fig. 317.

Plan to show augmentation of Surface by formation of Processes.

a, *b*, *c*. As in preceding figure. *d*. Simple, and *e*, *f*, branched or subdivided processes.

Some of the glands, as the lacteal and salivary, are granular in their arrangement; others, as the spermatic and urinary, consist of convoluted tubes; but all may be regarded as a prolongation of the skin; and the essential difference between the various secretory organs is in the extent occasionally of eversion but generally of inversion and convolution of the secretory membrane. This is well represented in the marginal figures.[4] The mor-

[1] Epist. Anatom. quâ respondet Viro Clarissimo Hermann. Boerhaav., p. 45, Lugd. Batav., 1722.

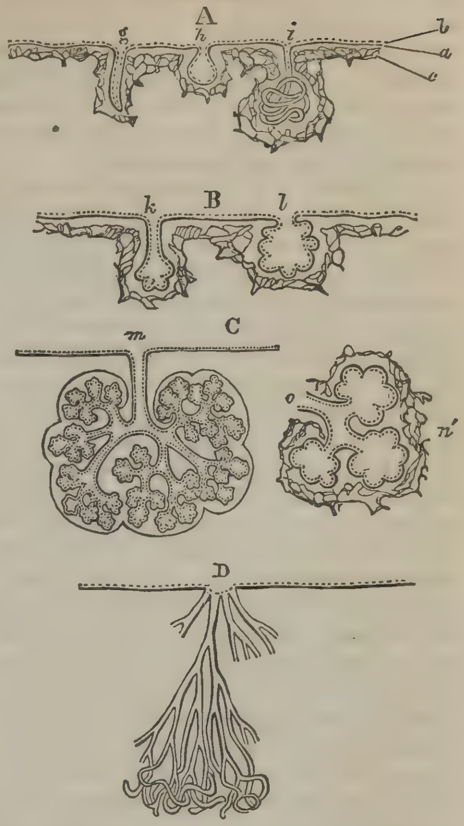
[2] Southwood Smith, in Animal Physiology, p. 115; Library of Useful Knowledge, Lond., 1829.

[3] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 238, Philad., 1849.

[4] Quain's Human Anatomy by Quain and Sharpey, Amer. edit. by Leidy, ii. 99, Philad., 1849.

phology of the secretory apparatus has been carefully investigated; but here—as elsewhere—we remain ignorant of the vital processes concerned. "We must not" —says Liebig[1]—"forget that anatomy alone, from the days of Aristotle to Leeuenhoek's time, has thrown but a partial light upon the laws of the phenomena of life, as the knowledge of the apparatus of distillation does not instruct us alone concerning its uses: so in many processes, as in distillation, he who understands the nature of fire, the laws of the diffusion of heat, and of evaporation, the construction of the still, and the products of distillation,—knows infinitely more of the process of distillation than the smith himself who made the apparatus. Each new discovery in anatomy has added acuteness, exactitude, and extent to its descriptions; unwearied investigation has almost penetrated to the inmost cell, from whence a new road of inquiry must be opened."

Fig. 318.



Plans of extension of Secreting Membrane, by inversion or recession in form of cavities.

A. Simple glands, viz., *g*, straight tube, *h*, sac, *i*, coiled tube. B. Multilocular crypts, *k*, of tubular form, *l*, saccular. C. Racemose or vesicular compound glands. *m*. Entire gland, showing branched duct and lobular structure. *n*. A lobule, detached with *o*, branch of duct proceeding from it. D. Compound tubular gland.

2. PHYSIOLOGY OF SECRETION.

The uncertainty which has rested on the intimate structure of secreting organs, and on the mode in which the different bloodvessels communicate with the commencement of the excretory duct, has enveloped the function, executed by those parts, in obscurity. We see the pancreatic artery pass to the pancreas; ramify in its tissues; become capillary, and escape detection; and other vessels becoming larger and larger, and emptying themselves into vessels of greater magnitude, until, ultimately, all the secreted humour is contained in one large duct, which passes onwards, and discharges its fluid into the small intestine. Yet if we follow the pancreatic artery as far back as the eye can carry

[1] Chemistry and Physics in relation to Physiology and Pathology, p. 105, Lond., 1846.

us, even when aided by glasses of considerable magnifying power, or if we trace back the pancreatic duct, we find, in the former vessel, always arterial blood, and in the latter, always pancreatic fluid. It must, consequently, be between the part at which the artery ceases to be visible, and at which the pancreatic duct becomes so, that secretion is effected; and we infer, that it occurs in the very tissue, parenchyma, or capillary system of the secreting organ.

Conjecture, in the absence of positive knowledge, has been busy, at all times, in attempting to explain the mysterious agency by which such various humours are separated from the same fluid; and, according as chemical, or mechanical, or exclusively vital doctrines have prevailed in physiology, the function has been referred to one or other of those agencies. The general belief amongst the physiologists of the sixteenth and seventeenth centuries was, that each gland possesses a peculiar kind of fermentation, which assimilates to its own nature the blood passing through it. The notion of fermentation was, indeed, applied to most of the vital phenomena. It is now totally abandoned, owing to its being purely imaginary, and inconsistent with all our ideas of the vital operations. When this notion had passed away, and the fashion of accounting for physiological phenomena on mechanical principles took its place, the opinion prevailed, that the secretions are effected through the glands as through filters. To admit of this mechanical result, it was maintained, that all the secreted fluids exist ready formed in the blood, and that, when they arrive at the different secretory organs, they pass through, and are received by the excretory ducts. Des Cartes[1] and Leibnitz[2] were warm supporters of this mechanical doctrine, although their views differed materially with regard to the precise nature of the operation. Des Cartes supposed, that the particles of the various humours are of different shapes, and that the pores of the glands have a corresponding figure; so that each gland permits those particles only to pass through it which have the shape of its pores. Leibnitz, on the other hand, likened the glands to filters, which had their pores saturated with their own peculiar substance, so that they admitted it to pass through them, and excluded all others,—as paper, saturated with oil, prevents the filtration of water. The mechanical doctrine of secretion was taught by Malpighi and Boerhaave,[3] and continued to prevail until the time of Haller. All the secretions were conceived to be ready formed in the blood, and the glands were looked upon as sieves or strainers to convey off the appropriate fluids or humours. In this view of the subject, all secretion was a transudation through the coats of the vessels,—particles of various sizes passing through pores respectively adapted for them.[4]

The mechanical doctrine of transudation, in this shape, is founded upon supposititious data; and the whole facts and arguments are so manifestly defective, that it is now abandoned. MM. Magendie and Fodéra have, however, revived the mechanical view of late years; but under an essentially different form, and one especially applicable to the

[1] De Homine, p. 11, Lugd. Bat., 1664. [2] Haller, Element. Physiol., vii. 3.
[3] Prælectiones Academicæ, &c., edit. A. Haller, § 253, Gotting., 1740–1743.
[4] Mascagni, Nova per Poros Inorganicos Secretionem Theoria., Rom., 1793, tom. ii.

exhalations. The former gentleman,[1] believing that many of these exist ready formed in the blood, thinks that the character of the exhaled fluid is dependent upon the physical arrangement of the small vessels, and his views repose upon the following experiments. If, in the dead body, we inject warm water into an artery passing to a serous membrane, as soon as the current is established from the artery to the vein, a multitude of minute drops may be observed oozing through the membrane, which speedily evaporate. If, again, a solution of gelatin, coloured with vermilion, be injected into the vessels, it will often happen, that the gelatin is deposited around the cerebral convolutions, and in the anfractuosities, without the colouring matter escaping from the vessels, whilst the latter is spread over the external and internal surfaces of the choroid. If, again, linseed oil, also coloured with vermilion, form the matter of the injection, the oil, devoid of colouring matter, is deposited in the articulations that are furnished with large synovial capsules; and no transudation takes place at the surface of the brain, or in the interior of the eye. M. Magendie asks, if these be not instances of true secretion taking place *post mortem*, and evidently dependent upon the physical arrangement of the small vessels; and whether it be not highly probable, that the same arrangement must, in part at least, preside over exhalation during life. M. Fodéra,[2] to whose experiments on the imbibition of tissues we had occasion to allude under the head of Absorption, embraces the views of M. Magendie, and so does Valentin.[3] If the vessels of a dead body, M. Fodéra remarks, be injected, the substance of the injection is seen oozing through them; and if an artery and a vein be exposed on a living animal, a similar oozing through the parietes is observable. This is more manifest if the trunk, whence the artery originates, be tied,—the fluid being occasionally bloody. If the jugular veins be tied, not only does œdema occur in the parts above the ligatures, but there is an increase of the salivary secretion. It is not necessary to refer to the various experiments of Fodéra relating to this topic, or those of Harlan, Lawrence and Coates, Dutrochet, Faust, Mitchell, and others. They are of the same character as those previously alluded to when treating of the imbibition of tissues; for transudation is only imbibition or soaking from within to without: MM. Magendie and Fodéra, indeed, conclude, that imbibition is a primary physical cause of exhalation as it is of absorption.

Another physical cause, adduced by M. Magendie, is the pressure experienced by the blood in the circulatory system, which, he thinks, contributes powerfully to cause the more aqueous part to pass through the coats of the vessels. If water be forcibly injected through a syringe into an artery, all the surfaces, to which the vessel is distributed, as well as the larger branches and the trunk itself, exhibit the injected fluid oozing in greater abundance according to the force exerted in the injection. He farther remarks, that if water be injected into the veins

[1] Précis, &c., edit. cit., ii. 444.

[2] Magendie's Journal de Physiologie, iii. 35; and Recherches, &c., sur l'Absorption et l'Exhalation, Paris, 1824.

[3] Lehrbuch der Physiologie des Menschen, Bd. 1, s. 601, Braunschweig, 1844.

of an animal, in sufficient quantity to double or treble the natural amount of circulating fluid, a considerable distension of the circulatory organs is produced, and the pressure is largely augmented. If any serous membrane be now examined,—as the peritoneum,—a watery fluid is observed issuing rapidly from it, which accumulates in the cavity, and produces a true dropsy under the eye of the experimenter; and, occasionally, the colouring part of the blood transudes at the surface of certain organs, as the liver, spleen, &c. Hamberger, again, broached the untenable physical hypothesis, that each secreted humour is deposited in its proper secretory organ by virtue of its specific gravity,[1]—but it is obvious, that all these speculations proceed upon the belief, that the exhalations exist ready formed in the blood; and that, consequently, the act of secretion, so far as concerns them, is one of separation or secerning,—not of fresh formation. That this is the case with the more aqueous secretions is probable, and not impossible with regard to the rest. Organic chemistry is subject to more difficulties in the way of analysis than inorganic; and it can be understood, that in a fluid so heterogeneous as the blood the discovery of any distinct humour may be impracticable. Of course, the elements of every fluid, as well as solid, must be contained in it; and we have already seen, that not merely the inorganic elements, but the organic or compounds of organization have been detected in it by the labours of Chevreul and others. There are indeed, some singular facts connected with this subject. MM. Prévost and Dumas,[2] having removed the kidneys in cats and dogs, and afterwards analyzed the blood, found urea in it—the characteristic element of urine. This principle was contained in greater quantity, the longer the period that had elapsed after the operation; whilst it could not be detected in the blood, when the kidneys were present. The experiment was soon afterwards repeated by MM. Vauquelin and Ségalas[3] with the same results. The latter introduced urea into the veins of an animal whose kidneys were untouched; he was unable to detect the principle in the blood; but the urinary secretion was largely augmented after the injection; whence he concludes, that urea is an excellent diuretic. Subsequently, MM. Gmelin and Tiedemann, in association with M. Mitscherlich,[4] arrived, experimentally, at the same conclusions as MM. Prévost and Dumas. The existence of urea in the fluid ejected from the stomach of the animal was rendered probable, but there were no traces of it in the fæces or the bile. The animal died the day after the extirpation of the second kidney. They were totally unable to detect either urea or sugar of milk in the healthy blood of the cow.

These circumstances would favour the idea, that certain of the secretions may be formed in the blood, and may simply require the intervention of a secreting organ to separate them;[5] but the mode in which such separation is effected is entirely inexplicable under the doctrine of

[1] Adelon, Physiologie de l'Homme, 2de édit., iii. 455, Paris, 1829.

[2] Annales de Chimie, tom. xxii. and xxxiii. 90.

[3] Magendie, Précis, &c., ii. 478.

[4] Tiedemann und Treviranus, Zeitschrift für Physiol., B. v. Heft i.; cited in Brit. and Foreign Med. Review, p. 592, for April, 1836.

[5] Dr. W. Philip, in Lond. Med. Gazette for March 25th, 1837, p. 952.

simple mechanical filtration or transudation. It is unlike any physical process that can be imagined. The doctrine of filtration and transudation can apply only to those exhalations in which the humour has undergone no apparent change; and it is obviously impossible to specify these, in the imperfect state of our means of analysis. In the ordinary aqueous secretions, simple transudation may embrace the whole process; and, therefore, it is unnecessary to have recourse to any other explanation; especially after the experiments instituted by M. Magendie, supported by pathological observations in which there has been partial œdema of the legs, accompanied by more or less complete obliteration of the veins of the infiltrated part,—the vessels being obstructed by fibrinous coagula, or compressed by circumjacent tumours. It is obvious, that ascites or dropsy of the peritoneum may be occasioned by obstruction of the portal circulation in the liver, and that in this way we may account for the frequency with which we find a union of hydropic and hepatic affections in the same individual. The same pathological doctrine, founded on direct observation, has been extended to phlegmasia dolens or swelled leg; an affection occurring in the puerperal state, and often found connected with obstruction in the great veins that convey the blood back from the lower extremity. It may not, consequently, be wide of the truth—if not wholly accurate—to consider certain of the secretions, with Dr. Billing,[1] to be "vital transudations from the capillaries into the excretory ducts of the glands, by pores invisible to our senses, even when aided by the most perfect optical instruments."

The generality of physiologists have regarded the more complex secretions—the follicular and glandular—as the results of chemical action; and under the view, that these secretions do not exist ready formed in the blood, and that their elements alone are contained in that fluid, it is impossible not to admit that chemical agency must be exerted. In support of the chemical hypothesis, which has appeared under various forms,—some, as Keill,[2] presuming that the secretions are formed in the blood, before they arrive at the place appointed for secretion; others, that the change is effected in the glands themselves, —the fact of the formation of a number of substances from a very few elements, provided these be united in different proportions, has been urged. Take, for example, the elementary bodies, oxygen and nitrogen. These, in one proportion, form atmospheric air; in another, nitrous oxide; in another, nitric oxide; in a fourth, hyponitrous acid; in a fifth, nitrous acid; in a sixth, nitric acid, &c., compounds which differ as much as the various secretions differ from each other and from the blood. Many of the compounds of organization likewise exhibit, by their elementary constitution, that but a slight change is necessary, in order that they may be converted into each other. Dr. Prout[3] has exhibited the close alliance between three substances—urea, lithic acid, and sugar,—and has shown how they may be converted into each other, by the addition or subtraction of single elements of their con-

[1] First Principles of Medicine, Amer. edit., p. 55, Philad., 1842.
[2] Tentamina Medico-Physica, iv.; and Haller, Element. Physiol., &c., lib. vii. sect. 3.
[3] Medico-Chirurg. Transact., viii. 540.

stituents. Urea is composed of two atoms of hydrogen, and one of carbon, oxygen, and nitrogen respectively; by removing one of the atoms of hydrogen and the atom of nitrogen, it is converted into sugar; by adding to it an additional atom of carbon, into lithic or uric acid. Dr. Bostock,[1]—who is disposed to push the application of chemistry to the explanation of the functions as far as possible,—to aid us in conceiving how a variety of substances may be produced from a single compound, by the intervention of physical causes alone, supposes the case of a quantity of materials adapted for the vinous fermentation being allowed to flow from a reservoir through tubes of various diameters, and with various degrees of velocity. "If we were to draw off portions of this fluid in different parts of its course, or from tubes, which differed in their capacity, we should, in the first instance, obtain a portion of unfermented syrup; in the next, we should have a fluid in a state of incipient fermentation; in a third, the complete vinous liquor; while, in a fourth, we might have acetous acid." Any explanation, however, founded upon this loose analogy, is manifestly too physical. Dr. Bostock admits this, for he subsequently remarks, that "if we adopt the chemical theory of secretion, we must conceive of it as originating in the vital action of the vessels, which enables them to transmit the blood, or certain parts of it, to the various organs or structures of the body, where it is subjected to the action of those reagents which are necessary to the production of these changes." The admission of such vital agency, in some shape, seems indispensable.

Attempts have been made to establish secretion as a nervous action, and numerous arguments and experiments have been brought forward in support of the position. That many of the secretions are affected by the condition of the mind is known to all. The act of crying, in evidence of joy or sorrow; the augmented secretion of the salivary glands at the sight of pleasant food; of the kidney during fear or anxiety; and the experimental confirmation, by Mr. Hunter, of the truth of the common assertion—that the she-ass gives milk no longer than the impression of the foal is on her mind,—the skin of the foal, thrown over the back of another, and frequently brought near her, being sufficient to renew the secretion,—sufficiently indicate, that the organs of secretion can be influenced through the nervous system in the same manner as the functions of nutrition and calorification.[2]

The discovery of galvanism naturally suggested it as an important agent in the process,—or rather suggested, that the nervous fluid strongly resembles the galvanic. This conjecture seems to have been first hazarded by Berzelius, and Sir Everard Home;[3] and, about the same time, an experiment was made by Dr. Wollaston,[4] which, he conceived, threw light on the process. He took a glass tube, two inches high, and three-quarters of an inch in diameter; and closed it at one

[1] Physiol., 3d edit, p. 519, Lond, 1836.

[2] For examples of the same kind, see Fletcher's Rudiments of Physiology, part ii. *b*, p. 10, Edinb., 1836; Burdach, Physiologie, u. s. w., § 522; and Dr. A. Combe, on Infancy, Amer. edit., chap. v., Philad., 1840.

[3] Lectures on Comp. Anat., iii. 16, London, 1816; and v. 154, London, 1828.

[4] Philosoph. Mag. xxxiii. 438.

extremity with a piece of bladder. He then poured into the tube a little water, containing $\frac{1}{240}$th of its weight of chloride of sodium, moistened the bladder on the outside, and placed it upon a piece of silver. On curving a zinc wire so that one of its extremities touched the piece of metal, and the other dipped into the liquid to the depth of an inch, the outer surface of the bladder immediately indicated the presence of pure soda; so that, under this feeble electric influence, the chloride of sodium was decomposed, and the oxide of sodium—soda—passed through the bladder. M. Fodéra[1] performed a similar experiment, and found, that whilst ordinary transudation frequently required an hour before it was evidenced, it was instantaneously exhibited under the galvanic influence. On putting a solution of cyanuret of potassium into the bladder of a rabbit, forming a communication with the solution by means of a copper wire; and placing on the outside a cloth soaked in a solution of sulphate of iron, to which an iron wire was attached; he found, by bringing these wires into communication with the galvanic pile, that the bladder or the cloth was suddenly coloured blue, according as the galvanic current set from without to within, or from within to without;—that is, according as the iron wire was made to communicate with the positive pole, and the copper wire with the negative, or conversely. But it is not necessary, that there should be communication with the galvanic pile. If an animal membrane, as a bladder, containing iron filings, be immersed in a solution of sulphate of copper, the sulphuric acid will penetrate the membrane to reach the iron, with which it forms a sulphate, and the metallic copper will be deposited on the lower surface of the membrane; the animal membrane, in such case, offering no obstacle to the action of the ordinary chemical affinities.

With some of the chemical physiologists, there has been a disposition to resolve secretion into a mere play of electric affinities. Thus, M. Donné[2] affirms, that from the whole cutaneous surface an acid humour is secreted, whilst the digestive tube, except in the stomach, secretes an alkaline mucus: hence, he infers, that the external *acid*, and the internal *alkaline* membranes of the human body represent the two poles of a pile, the electrical effects of which are appreciable by the galvanometer. On placing one of the conductors of the instrument in contact with the mucous membrane of the mouth, and the other with the skin, the magnetic needle deviated fifteen, twenty, and even thirty degrees, according to its sensibility; and its direction indicated, that the mucous or alkaline membrane took negative, and the cutaneous membrane, positive electricity. He further asserts, that, between the *acid* stomach and the *alkaline* liver, extremely powerful electrical currents are formed. These experiments do not, however, aid us materially in our solution of the phenomena of secretion. They exhibit merely electrical phenomena dependent upon difference of chemical composition. This is, indeed, corroborated by the experiments of M. Donné himself on the secretions of vegetables. He observed electrical phenomena of the same kind in them; but, he says, electrical currents

[1] Magendie's Journal de Physiologie, iii. 35; and Recherches, &c., sur l'Absorption et l'Exhalation, Paris, 1824.

[2] Annales de Chimie, &c., lvii. 400; and Journal Hebdomad., Fév., 1834.

in vegetables are not produced by the acid or alkaline conditions of the parts as in animals, the juice of fruits being always more or less acid. Experiments of M. Biot, however, show, that the juices, which arrive by the pedicle, are modified in some part of the fruit, and M. Donné thinks it is perhaps to this difference in the chemical composition of the juices of the two extremities, that the electrical phenomena are to be attributed.

The effects of the section of the pneumogastric nerves on the functions of digestion and respiration have been given elsewhere, at some length. It was then stated, that when digestion was suspended by their division, Dr. Wilson Philip[1] was led to ascribe it to the secretion of the gastric juice having been arrested; an opinion, which Sir B. Brodie had been induced to form previously, from the results of experiments, which showed, that the secretion of urine is suspended by the removal or destruction of the brain; and that when an animal is destroyed by arsenic, after the division of the pneumogastric nerves, all the usual symptoms are produced, except the peculiar secretion from the stomach. Sir B. Brodie did not draw the conclusion, that the nervous influence is absolutely necessary to secretion, but that it is a step in the process; and the experiments of M. Magendie[2] on the effect of division of the nerve of the fifth pair on the nutritive secretion of the cornea, confirm the position. We have, indeed, numerous evidences, that the nervous system cannot be indispensable to secretion. In all animals, this power must exist; yet there are some in which no nervous system is apparent. Dr. Bostock[3] has given references to cases of monstrous or deformed fœtuses, born with many of their organs fully developed, yet in which there was apparently no nervous system. It may be said, however, that, in all these cases, a rudimental nervous system may and must have existed; but setting aside the case of animals, secretion is equally effected in the vegetable, in which there is no nervous system; yet the function is accomplished as perfectly, and perhaps in as multiple a manner, as in animals. It is manifest, therefore, that this is one of the vital actions occurring in the very tissue of organs, of which we have no more knowledge than we have of the nutritive actions in general. All that we know is, that in special organs various humours are secreted from the blood, some of which can be detected in that fluid; others not.

The doctrine of developement by cells was an important step in the inquiry. It has been elsewhere shown how cells are considered to effect the work of absorption; and secretion is probably accomplished in a similar manner. It is essentially a function of nucleated cells,—such cells possessing a peculiar organic power by virtue of which they can draw into their interior certain kinds of materials varying according to the nature of the fluid they are destined to secrete.[4] Some cells have merely to separate certain ingredients from the surrounding medium; others have to elaborate within themselves matters that do not exist as

[1] London Medical Gazette, March 18, and March 25, 1837.
[2] Précis, &c., ii. 489. [3] Physiology, edit. cit., p. 525, Lond., 1836.
[4] Professor Goodsir, Transactions of the Royal Society of Edinburgh, 1842, and Anatomical and Pathological Observations, Edinb., 1845.

such in the nutritive medium. Although secreting cells thus differ in the nature of the fluid which they secrete, their structure seems to be nearly the same in all cases,—each consisting, like other primitive cells, of a nucleus, cell-wall, and cavity. The nucleus appears to be both the reproductive organ by which new cells are generated, and the agent for separating and preparing the secreted material. The cell-cavity seems chiefly destined to contain the secreted fluid until ready to be discharged; at which time the cell, then matured, bursts and discharges its contents into the outer cellular space on which it is situate, or upon a free surface, as the case may be.

The mode of secretion in glands, of which Professor Goodsir takes the testicle of the *squalus cornubicus* as a type, appeared to him to be as follows. Around the extremities of the minute ducts of the glands are developed acini or primary nucleated cells, each of which, as it increases in size, has generated, within it, secondary cells—the product of its nucleus. The cavity of the parent cell does not communicate with the duct on which it is situate until its contents are fully matured, at which time the cell-wall bursts or dissolves away, and its contents are discharged into the duct. From this constant succession of growth and solution of cells it results, that the whole parenchyma of a gland is continually passing through stages of developement, maturity, and atrophy,—the rapidity of the process being in proportion to the activity of the secretion. There seems, consequently, in this view of the subject, to be no essential difference between the process of secretion, and the growth of a gland: the same cells are the agents by which both are effected. The parenchyma of glands is chiefly made up of a mass of cells in all stages of developement: as these cells individually increase in size, and so constitute their own growth as well as that of the common glandular mass, they are at the same time elaborating within themselves the material of secretion, which, when matured, they discharge by dissolving away. There are numerous germinal spots or centres in a gland, from which acini or primary cells are developed. The true fluid of secretion, in Mr. Goodsir's opinion, is not the product of the parent cell of the acinus, but of its included mass of secondary cells, which themselves become primary secreting cells, and form the material of secretion in their cavities. In some cases, these secondary cells pass out entire from the parent cell, constituting a form of secretion in which the cells possess the power of becoming more fully developed after being discharged and cast into the duct or cavity of the gland. He considers growth and secretion to be identical—the same process under different circumstances,—a view which had indeed been already embraced by others, and which ought to be universally. It must be recollected, that bloodvessels, like absorbents, are shut sacs; and, therefore, the materials for nutrition and secretion must pass either through them in the manner suggested by Mr. Goodsir, or by transudation. Transudation, however, would seem to be mainly, if not wholly, applicable to tenuous fluids only; whilst every solid in the body must be nourished by materials obtained from the blood. The agency of cells in nutrition and secretion may, therefore, be regarded as established.

Mr. Addison[1] has suggested, that these cells are not developed in the organs of nutrition and secretion at the expense of materials supplied by the blood; that they are neither more nor less than the colourless corpuscles of the blood, which elaborate those products whilst still floating in its current, and then escape from the vessels. It is not easy, however, to comprehend, that corpuscles, apparently identical, should exist in the blood charged with the different properties of separating bile, urine, saliva, &c., from the fluid; or that they could escape through the parietes of the containing bloodvessels, and then penetrate the parietes of the excretory ducts to take their place—it has been supposed—as epithelium cells on the lining membrane of these outlets. Moreover, as has been shown elsewhere, there is reason to believe, that the office of the white corpuscles of the blood is of a different character.[2]

In cases of vicarious secretion, we have the singular phenomenon of organs assuming an action for which they were not destined. If the secretion from the kidney, for example, be arrested, urine is occasionally found in the ventricles of the brain, and, at other times, a urinous fluid has been discharged by vomiting or by cutaneous transpiration: the secreting cells of those parts must, consequently, have assumed the functions of the kidney, and to this they were excited by the presence of urea, or the elements of the urinary secretion in the blood,—a fact, which exhibits the important influence that the condition of the blood must exert on the secretions, and, indeed, on nutrition in general. It is thus that many of our remedial agents, alkalies, the preparations of iodine, &c.,—produce their effects. They first enter the mass of blood, and, by circulating in the capillary system, induce a modification of the function of nutrition. There are other cases, again, in which the condition of the blood being natural, the cells of nutrition may assume morbid action. Of this we have examples in the ossification of organs, which, in the healthy condition, have no bony constituent; in the deposition of fat in cases of diseased ovaria; and in the altered secretions produced by any source of irritation in a secreting organ.

In describing the physiology of the different secretions, one of three arrangements has usually been adopted; either according to the nature of the secreting organ, the function of the secreted fluid, or its chemical character. The first of these has been followed by MM. Bichat and Magendie,[3] who have adopted a division into *exhaled*, *follicular*, and *glandular* secretions. It is the one followed by M. Lepelletier, except that he substitutes the term *perspiratory* for *exhaled*. According to the second, embraced by MM. Boyer,[4] Sabatier,[5] and Adelon,[6] they are divided into *recrementitial*, or such as are taken up by internal absorption and re-enter the circulation; and *excrementitial*, or such as are evacuated from the body, and constitute the excretions. Some physiologists add a third—the *recremento-excrementitial*,—in which a

[1] The Actual Process of Nutrition on the Living Structure demonstrated by the Microscope, &c., Lond., 1844.

[2] See p. 109 of this volume.

[3] Précis de Physiologie, 2de édit., ii. 243, Paris, 1825.

[4] Anatomie, 2de édit., i. 8, Paris, 1803.

[5] Traité Complet d'Anatomie, Paris, 1791.

[6] Physiologie de l'Homme, edit. cit., iii. 438.

part of the humour is absorbed and the remainder ejected. Lastly, the division according to chemical character has been followed, with more or less modification, by Plenck,[1] Richerand,[2] Blumenbach,[3] Young,[4] and Bostock;[5] the last of whom has eight classes; the *aqueous*, *albuminous*, *mucous*, *gelatinous*, *fibrinous*, *oleaginous*, *resinous*, and *saline*. To all of these classifications cogent objections might be made. The one we shall follow is the anatomical,—not because it is the most perfect, but because it is the course that has been usually adopted throughout this work. Defective, too, as it is, it will enable us to take a survey of every one of the numerous secretions classified in the following

TABLE OF THE SECRETIONS.

I. Exhalations.	A. Internal.	1. Of the areolar membrane.	
		2. Of the serous membranes.	
		3. Of the synovial membrane.	
		4. Of the adipous membrane.	a. Fat. b. Marrow.
		5. Of the pigment membrane.	
		6. Of areolar capsules.	
	B. External.	1. Of mucous membranes.	General and pulmonary.
		2. Menstrual.	
		3. Gaseous.	
II. Follicular Secretions.		1. Of mucous membranes.	Gastro-pulmonary, genito-urinary, &c.
		a. Of the Peyerian glands.	
		b. Of the ovaria.	
		2. Of the skin.	
		a. Sebaceous.	
		b. Meibomian.	
		c. Ceruminous.	
		d. Preputial.	
		e. Odoriferous.	
III. Glandular Secretions.		1. The transpiratory.	
		2. The lachrymal.	
		3. The salivary.	
		4. The pancreatic.	
		5. The biliary.	
		6. The urinary.	
		7. The spermatic.	
		8. The lacteal.	

I. EXHALATIONS.

All the exhalations take place into the areolæ and internal cavities of the body, or from the skin and mucous membranes;—hence their division into *internal* and *external*. The former are *recrementitial*, the latter *recremento-excrementitial*. To the class of *internal exhalations* belong: 1. The areolar exhalation. 2. The serous exhalation. 3. The synovial exhalation. 4. The adipous exhalation. 5. The pigmental exhalation. 6. The exhalation of the areolar capsules. To

[1] The Chemico-Physiological Doctrine of the Fluids, &c., translated by Dr. Hooper, Lond., 1797.

[2] Elémens de Physiologie, 13ème édit., chap. vi., Bruxelles, 1837.

[3] Physiology, by Elliotson, 4th edit., Lond., 1828.

[4] Introduction to Medical Literature, p. 104, Lond., 1813.

[5] Physiology, 3d edit., p. 48, Lond., 1836.

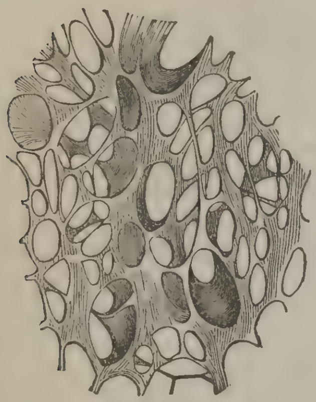
the class of *external exhalations* belong: 1. The exhalation of the mucous membranes. 2. The menstrual exhalation; and 3. Gaseous exhalations.

A. INTERNAL EXHALATIONS.

1. *Exhalation of the Areolar Membrane.*

A brief view of the nature of the primary *areolar cellular* or *fibro-cellular* membrane was given in an early part of this work (vol. i. p. 58). As we observe it, it is not properly cellular, but is composed of a network of fibres, and lamellæ formed by the adhesion of fibres laid

Fig. 319.



Portion of Areolar Tissue inflated and dried, showing the general character of its larger meshes; magnified twenty diameters. (Todd and Bowman.)

Fig. 320.

Arrangement of Fibres in Areolar Tissue.—Magnified 135 diameters.

side by side; and these interwoven so as to leave numerous interstices and areolæ amongst them, which have a tolerably free communication with each other.[1]

Two kinds of fibrous tissue—the *white* and the *yellow*—may be detected in it,—the *white* presenting itself in the form of inclastic bands, the largest $\frac{1}{500}$th of an inch in breadth, somewhat wavy in their direction, and marked longitudinally by numerous streaks; and the *yellow* existing in the form of long, single, elastic, branched filaments, with a dark decided border, and disposed to curl when not put upon the stretch. These interlace with the others, but seem to have no continuity of substance with them. They are, for the most part, between the $\frac{1}{5000}$th and $\frac{1}{10000}$th of an inch in thickness; but are often met with both larger and smaller.

The interstices in the areolar membrane, wherever existing, are kept

[1] For the histology of the areolar and serous membranes, see Todd and Bowman, Physiological Anatomy and Physiology of Man, London, 1842; and Dr. Brinton, art. Serous and Synovial Membranes, Pt. xxxiv. p. 512, Lond., Jan., 1849.

moist by a serous fluid, analogous to that exhaled from serous membranes, and which appears to have the same uses,—that of facilitating the motion of the lamellæ, or fibres on each other, and, consequently,

Fig. 321.

White Fibrous Tissue, from Ligament.—Magnified 65 diameters.

Fig. 322.

Yellow Fibrous Tissue, from Ligamentum Nuchæ of Calf.—Magnified 65 diameters.

of the organs between which the areolar tissue is placed. When this secretion collects, from the causes mentioned in the last section, the disease called *œdema* or *anasarca* is induced.

2. *Exhalation of the Serous Membranes.*

This is the fluid secreted by the serous membranes that line the various cavities of the body;—as the pleura, pericardium, peritoneum, arachnoid coat of the brain, tunica vaginalis testis, and the lining membrane of the vessels. Rudolphi[1] asserts, that serous membranes are incapable of inflammation, are not vascular, and do not secrete; and that the secretions of shut sacs take place from the subjacent parts, and transude through the serous membrane, which, consequently, in his view, is a kind of cuticle. In a physiological consideration, it is not of moment whether they resemble the cuticle or not; and anatomically the question only concerns the layer that covers the surface.

Serous membranes, as elsewhere remarked, form shut sacs, and invest viscera, whose free surfaces come in contact, or which lie in cavities unattached to surrounding parts. To the law, that they form close or shut sacs, there is but one exception in the human subject; in the opening of the Fallopian tubes into the cavity of the abdomen.

They are constituted of fibro-areolar tissue so interwoven as to constitute a membrane,—the free surface covered with a layer of flattened cells forming, in most cases, a *tesselated epithelium.*[2] Between the epithelium and subserous areolar tissue is the *primary* or *basement membrane.*[3] The basement membrane and epithelium are concerned in the secretion of the fluid by which the free surface of the membrane

[1] Grundriss der Physiologie, § 113, Berlin, 1821. [2] See vol. i. p. 132.

[3] Bowman, art. Mucous Membrane, Cyclopædia of Anatomy and Physiology, p. 484, April, 1842.

is moistened. The general arrangement of serous membranes has been well described by Professor Goodsir.[1] A portion of the human pleura or peritoneum, according to him, consists, from its free surface inwards, of a single layer of nucleated scales; of a germinal membrane, and of a subserous areolar texture intermixed with occasional elastic fibres. The bloodvessels of the serous membrane ramify in the areolar texture. The germinal membrane seldom shows the lines of junction of its component flattened cells. These appear elongated in the form of ribands,—their nuclei or the germinal spots of the membrane being elongated, expanded at one extremity, pointed at the other, and somewhat bent upon themselves; they are bright and crystalline, and may or may not contain smaller cells in their interior. If these germinal centres be the sources of all the scales of the superficial layer, each centre being the source of the scales of its own compartment, then the matter necessary for the formation of these during their developement must pass, he conceives, from the capillary vessels to each of the centres, acted on by forces whose centres of action are the germinal spots;—each of the scales, after being detached from its parent centre, deriving its nourishment by its own inherent powers.

From these membranes a fluid is exhaled, which is of an albuminous character, resembling greatly the serum of the blood, except in containing less albumen. M. Donné[2] says it is always alkaline in the healthy state. This is owing to the presence of carbonate or albuminate of soda. It contains 7 or 8 per cent. of albumen, and salts. In health, this fluid never accumulates in the cavities,—the absorbents taking it up in proportion as it is deposited; but if, from any cause, the exhalants should pour out a larger quantity than usual, whilst the absorbents are not proportionably excited, accumulation may take place; or the same effect may ensue if the exhalants pour out no more than their usual quantity, whilst the absorbents do not possess their due activity. Under either circumstance, we have an accumulation—a dropsy. The exhaled fluid probably transudes through the parietes of the arteries, and re-enters the circulation by imbibition through the coats of the veins. If we kill an animal and open it immediately afterwards, this exhalation appears in the form of a halitus or vapour, and the fluid is seen lubricating the free surface of the membrane. This, indeed, appears to be its principal office; by which it favours the motion of the organs upon each other.

The serous exhalations probably differ somewhat in each cavity, or according to the precise structure of the membrane. The difference between the chemical character of the fluid of the dropsy of different cavities would lead to this belief. As a general rule, according to Dr. Bostock,[3] the fluid from the cavity of the abdomen contains the greatest proportion of albumen, and that from the brain the least; but many exceptions occur to this.

1 Anatomical and Pathological Observations, Edinb., 1845.
2 Journal Hebdomad., Février, 1834.
3 Op. citat., p. 485.

3. *Exhalation of the Synovial Membrane.*

Within the articular capsules, and bursæ mucosæ,—which have been described under Muscular Motion,—a fluid is secreted, which is spread over the articular surfaces of bones, and facilitates their movements. Dr. Clopton Havers[1] considered this fluid to be secreted by *synovial glands*,—for such he conceived the reddish cellular masses to be, that are found in certain articulations. Haller[2] strangely regarded the synovia as the marrow, which had transuded through the spongy extremities of the bones; but, since the time of Bichat, every anatomist and physiologist has ascribed it to the exhalant action of the synovial membrane, which strongly resembles the serous membranes in form, structure, and functions, whose folds constitute the projections that Havers mistook—it was conceived—for glands. The opinion of Havers has, however, been lately confirmed by Mr. Rainey.[3] It had been believed by many, that the folds of synovial membrane, which form fringes, contain merely globules of fat, and are only inservient to the mechanical office of filling up spaces that would otherwise be left vacant during the movements of the joints. By a careful examination of their structure, with the aid of the microscope, Mr. Rainey found a peculiar arrangement of vessels not at all resembling those that secrete fat, and an epithelium of remarkable form and disposition, and characteristic of organs whose function it is to effect a special secretion. These fringes he traced not only in the joints but in the sheaths of tendons, and in the bursæ—wherever, indeed, synovia is secreted. When well injected they are seen under the microscope to consist of a convolution of bloodvessels and an investing epithelium, which, besides enclosing separately each packet of convoluted vessels, sends off from each tubular sheath secondary processes of various shapes into which no bloodvessels enter. The lamina itself forming these folds and processes consists of a very thin membrane studded with flattish oval cells, a little larger than blood corpuscles, but destitute of nucleus or nucleolus,—presenting none of the characters of tesselated epithelium, but corresponding more to what Mr. Goodsir has termed "germinal membrane." From this morphological arrangement, Mr. Rainey accords with Havers in the view, that the proper office of the structure is to secrete synovia.

The synovial membrane exists in all the movable articulations, and in the channels and sheaths in which the tendons play. The generality of anatomists regard the articular capsules as shut sacs; the membranes being reflected over the incrusting cartilages. M. Magendie, however, affirms, that he has several times satisfied himself, that they do not pass beyond the circumference of the cartilages. From the inner surface of these membranes the synovia is exhaled in the same manner as in other serous cavities.

M. Margueron[4] analyzed synovia obtained from a posterior extremity of the ox, and found it consist of fibrous matter, 11·86; albumen, 4·52;

[1] De Ossibus, serm. iv. c. 1; and Osteologia Nova, London, 1691.
[2] Element. Physiol., iv. 11.
[3] Proceedings of the Royal Society of London, No. 65, 1847.
[4] Annales de Chimie, xiv. 123.

chloride of sodium, 1·75; soda, 0·71; phosphate of lime, 0·70; and water, 80·46. M. Donné[1] says it is always alkaline in health; but in certain diseases sometimes becomes acid. The synovia of a stall fed ox was found by Frerichs[2] to consist of

Water,	969·90
Solid constituents,	30·10
Mucous matter with epithelium,	2·40
Fat,	0·62
Albumen and extractive matter,	15·76
Salts,	11·32

That of an ox, which had been pasture-fed all the summer, contained

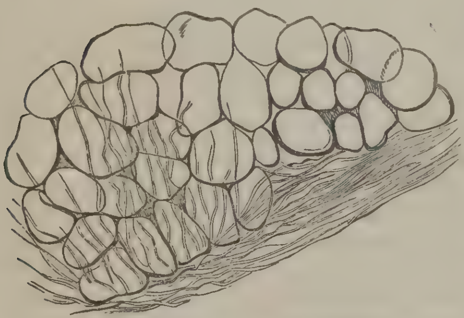
Water,	948·54
Solid constituents,	51·46
Mucous matter and epithelium,	5·60
Fat,	0·76
Albumen and extractive matter,	35·12
Salts,	9·98

4. *Areolar Exhalation of the Adipous Membrane.*

a. Fat.

Considerable diversity of opinion has prevailed regarding the precise organ for the secretion of fat. Haller supposed, that the substance exists ready formed in the blood, and simply transudes through the pores of the arteries; and Chevreul and others have given some countenance to the opinion, by the circumstance of their having met with fatty matter in that fluid. Anatomists have, likewise, been divided upon the subject of the precise tissue into which the fat is deposited; some believing it to be the ordinary areolar tissue, into which it is dropped by the agency of appropriate vessels; others, as Malpighi[3] and Dr. William Hunter,[4] believing in the existence of a peculiar adipous tissue, consisting, according to M. Béclard,[5] of small bursæ or membranous vesicles, which enclose the fat, and are found in the areolæ of the tissue. These vesicles are said to vary greatly in size: generally, they are round and globular; and, in certain subjects, receive very apparent vessels. They form so many small sacs without apertures, in the interior of which are filaments arranged like septa. In fatty subjects, these adipous vesicles are very perceptible, being

Fig. 323.



A small cluster of Fat-Cells magnified 150 diameters.

[1] Journal Hebdomad., Février, 1834.

[2] Art. Synovia, in Wagner's Handwörterbuch der Physiologie, 18te Lieferung, s. 467, Braunschweig, 1848.

[3] De Omento, Pinguedine, et Adiposis Ductibus, in Oper., London, 1687.

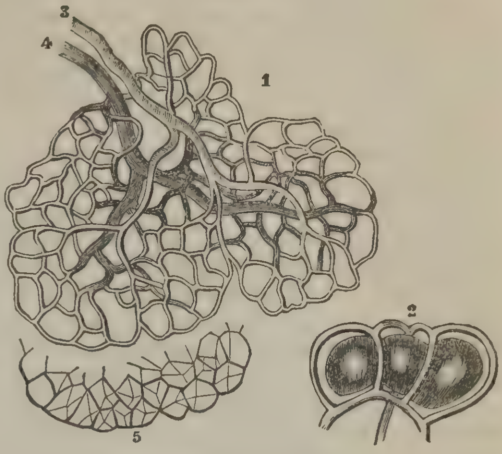
[4] Medical Observations and Inquiries, vol. ii., London, 1577.

[5] Art. Adipeux, in Dictionnaire de Médecine, tom. i.; and Elements of General Anatomy, translated by Togno, p. 128, Philad., 1830.

attached to the areolar tissue and neighbouring parts by a vascular pedicle.

The fat originates from fat-cells, which are usually of a spherical or spheroidal shape, but sometimes, when closely pressed together without the intervention of any intercellular substance, they become polyhedral. The adipous tissue is a membrane of extreme tenuity, which forms the vesicle that includes the fat. The membrane is homogeneous and transparent, about the $\frac{1}{20000}$th of an inch thick, and is moistened by a watery fluid, for which it has a greater attraction than the fat it contains. Each vesicle is from the $\frac{1}{300}$th to the $\frac{1}{800}$th of an inch in diameter. When the fat vesicles exist in any number, their arrangement is generally lobular, with an investment of areolar tissue, which favours motion, and the distribution of the bloodvessels. These enter the interlobular clefts, ramify through their interior as a solid capillary network, occupy the angles formed by contiguous sides of the vesicles, and anastomose with one another at the points where these angles meet.

Fig. 324.



Bloodvessels of Fat Vesicles.

1. Minute flattened fat-lobule, in which the vessels only are represented. 3. Terminal artery. 4. Primitive vein. 5. Fat vesicle, of one border of the lobule, separately represented. Magnified 100 diameters.—2. *Plan* of the arrangement of capillaries on the exterior of the vesicles, more highly magnified.

M. Raspail[1] affirms, that there is the most striking analogy between the nature of the adipous granules and that of the amylaceous grains. As in the case of fecula, each adipous granule is composed of at least one integument, and an enclosed substance, both of which are as slightly nitrogenized as fecula; and both fecula and fat are equally inservient to the nutrition of the organs of developement: whenever there is excess of life and activity, the fat is seen to disappear, and whenever there is rest, it accumulates in its reservoirs. If a portion of fat be examined, it is found to consist of an outer vesicle with strong membranous parietes, containing small adipous masses readily separable from each other, each invested with a similar, but slighter, vesicular membrane; and these, again, contain others still more minute, until ultimately we come to the vesicles that invest the adipous granules themselves. Each of these masses adheres, at some point of its surface, to the inner surface of the vesicle that encloses it, by a hilum in the same manner as the grain of fecula. All the vesicles, but especially the outermost and

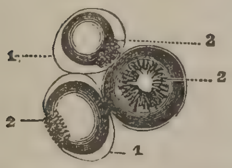
[1] Chimie Organique, p. 183, Paris, 1833.

strongest, have a reddish vascular network on their surface, the vessels of which augment in size as they approach the part where the vesicle is adherent, and there open into one of the vessels of the larger vesicle that encloses them.

The arrangement of this tissue, as well as the quantity of fat, varies in different parts of the body. It is always found in the orbit, on the sole of the foot, and at the pulps of the fingers and toes. The subcutaneous areolar tissue, and that covering the heart, kidneys, &c., also generally contain it; but it is never met with in the eyelids, scrotum, or within the cranium.

Fat is exhaled by the secretory vessels in a fluid state; but after it is deposited, it becomes more or less solid. According to the researches of MM. Chevreul[1] and Braconnot, human fat is almost always of a yellow colour; inodorous, and composed of two portions;—the one fluid, and the other concrete, which are themselves composed, but in different proportions, of two immediate principles, to which the former chemist gave the names *elain* or *olein*, and *stearin*. Subsequently, the organic elements of fat were considered to be *stearin*, *margarin*, and *olein;* the two former, which are solid when separate, being dissolved in the latter at the ordinary temperature of the body. Chemistry has, however, shown, that the fat contained in the cells of the adipous tissue is composed of a base of a sweetish taste, thence termed *glycerin*, itself an oxide of glyceryl with stearic, margaric, and oleic acids,—stearin being esteemed a bi-stearate of glycerin; and olein or elain an oleate of glycerin. These proximate principles are sometimes seen spontaneously separated within the human fat vesicle. The stearin collects in the form of a small star on the inner surface of the membrane, as in the marginal figure at 2, 2, 2, the elain occupying the remainder of the vesicle, except where there is an unusually small quantity of fat, when a little aqueous fluid is seen interposed between the elain and the cell-membrane.

Fig. 325.



Fat Vesicles from an Emaciated Subject.

1, 1. Cell-membrane. 2, 2, 2. Solid portion collected as a star-like mass, with the elain in connexion with it, but not filling the cell.

It is probable, that chemical analysis would exhibit the fat to vary in different parts of the body, as its sensible properties are different. Sir Everard Home,[2] on loose analogies and inconclusive arguments, has advanced the opinion, that it is more than probable, that fat is formed in the lower portion of the intestines; and thence is carried, through the medium of the circulating blood, to be deposited in almost every part of the body. "When there is a great demand for it, as in youth, for carrying on growth, it is laid immediately under the skin, or in the neighbourhood of the abdomen. When not likely to be wanted, as in old age, it is deposited in the interstices of muscular fibres, to make up in bulk for the wasting of these organs." M. de Blainville[3] held the opinion, that fat is derived from venous blood, and that it is exhaled

[1] Recherches Chimiques sur les Corps Gras, &c., Paris, 1823.

[2] Lect. on Comp. Anat., i. 468, Lond., 1814, and vol. vi. Lond., 1828; and Philos. Transact., 1821, p. 34.

[3] De l'Organisation des Animaux, &c., Paris, 1825.

through the coats of the vessels. This opinion he founds on the mode in which the fat is distributed in the omenta along the course of the veins; and he affirms, that he has seen it flow out of the jugular vein in a dead elephant. But this last fact, as M. Lepelletier[1] has judiciously remarked, proves nothing more than that fat—taken up by the absorbents from the vesicles in which it had been deposited by the exhalants—had been conveyed into the venous blood with other absorbed matters. It in no wise shows, that the venous blood is the pabulum of the secretion, or that the veins accomplish it.

The purposes served by the fat are both *general* and *local*. The great general use is, by some physiologists, conceived to be,—to serve as a provision in cases of wasting indisposition; when the digestive function is incapacitated for performing its due office, and emaciation is the consequence. In favour of this view, the rapidity with which fat disappears after slight abstinence has been urged, as well as the facts, connected with the torpidity of animals, which are always found to diminish in weight during this state. Professor Mangili, of Pavia, procured two marmots from the Alps, on the 1st of December. The larger weighed 25 Milanese ounces; the smaller only $22\frac{1}{8}$th; on the 3d of January, the larger had lost $\frac{3}{4}$ths of an ounce, and the smaller $\frac{1}{2}\frac{7}{4}$ths. On the 5th of February, the larger weighed only $22\frac{7}{8}$; the smaller 21. Dr. Monro kept a hedgehog from the month of November to the month of March following, which lost, in the meanwhile, a considerable portion of its weight. On the 25th of December, it weighed 13 ounces and 3 drachms; on the 6th of February, 11 ounces and 7 drachms; and on the 8th of March, 11 ounces and 3 drachms. The loss was 13 grains daily.[2]

The local uses of fat are chiefly of a physical character. On the sole of the foot it diminishes the effects of pressure, and serves the same office on the nates; in the orbit it forms a kind of cushion, on which the eyeball moves with facility; and when in certain limits, it gives that rotundity to the frame, which we are accustomed to regard as symmetry. Dr. Fletcher,[3] indeed, considers its principal use to be, to fill up interstices, and thus to give a pleasing contour to the body. In another place, it was observed, that fatty substances are bad conductors of caloric; and hence may tend to preserve the temperature of the body in cold seasons; a view which is favoured by the fact, that many of the Arctic animals are largely supplied with fat beneath the common integuments; and it has been affirmed, that fat people generally suffer less than lean from the cold of winter.

It is obviously impracticable to estimate accurately the total quantity of fat in the body. It has been supposed that, in an adult male of moderate size, it forms $\frac{1}{20}$th of the whole weight; but it is doubtful whether we ought to regard this as even an approximation,—the data being so inadequate. In some cases of polysarcia or obesity, the bulk of the body has been enormous. That of a girl is detailed, who weighed

[1] Physiologie Médicale et Philosophique, ii. 496, Paris, 1832.
[2] Fleming, Philosophy of Zoology, ii. 59, Edinb., 1822.
[3] Rudiments of Physiology, part iii., by Dr. Lewins, p. 71, Edinb., 1837.

256 pounds, when only four years old.[1] A girl, said to be only ten years old, called the "Ohio giantess," was exhibited in Philadelphia, in the year 1844, who was said to weigh 265 pounds; and in March, 1847, an Ohio girl, twelve years of age—perhaps the same—was exhibited, who weighed 330 pounds. The Lowell Advertiser, of September, 1844, states, that a coloured girl, aged fourteen, a native of Nassau, New York, died in that city, weighing 500 pounds. A man of the name of Bright, at Malden, England, weighed 728 pounds; and the celebrated Daniel Lambert, of Leicester, England, weighed 739 pounds a little before his death, which occurred in the fortieth year of his age.[2] The circumference of his body was three yards and four inches; and of his leg one yard and one inch. His coffin was six feet four inches long; four feet four inches wide; and two feet four inches deep. A Kentuckian, of the name of Pritchard, who exhibited himself in Cincinnati, in 1834, weighed five hundred and fifty pounds. The "Canadian giant,"—as he was called—whom Dr. Gross[3] saw in Philadelphia, in 1829, weighed six hundred and eighteen pounds. He was six feet four inches in height, and the circumference of each leg around the calf was nearly three feet. The deposition of fat was confined chiefly to the abdomen and lower limbs,—the thorax, shoulders, and arms being little larger than in other persons. The public Journals of this country[4] have also recorded the death of a Mr. Cornelius, who weighed 720 pounds. Dr. Elliotson[5] says he saw a female child, but a year old, which weighed sixty pounds. She had begun to grow fat at the end of the third month.

In these cases, the specific gravity of the body may be much less than that of water. It is said, that some time ago there was a fat lighterman, on the river Thames, "who had fallen overboard repeatedly, without any farther inconvenience than that of a good ducking; since though he knew nothing whatever of the art of swimming, he always continued to flounder about like a firkin of butter, till he was picked up."[6]

In some of the varieties of the human family we meet with singular adipous deposits. In the Bosjesman female vast masses of fat accumulate on the buttocks, which give them the most extravagant appearance. The projection of the posterior part of the body, in one subject, according to Sir John Barrow,[7] measured five inches and a half from a line touching the spine. "This protuberance," he remarks, "consisted of fat, and when the woman walked, had the most ridiculous appearance imaginable, every step being accompanied with a quivering and tremulous motion, as if two masses of jelly were attached behind." The "Hottentot Venus," who had several projections, measured more than nineteen inches around the haunches; and the projection of the hips exceeded $6\frac{1}{3}$ inches. Dr. Somerville[8] found on dissection, that the

1 Philos. Transact., No. 185.
2 Good's Study of Medicine, Class vi. Ord. 1, Gen. 1, Sp. 1.
3 Elements of Pathological Anatomy, 2d edit., p. 202, Philad., 1845.
4 Philadelphia Public Ledger, October 4, 1841.
5 Human Physiology, London, 1841, P. i. 301.
6 Fletcher, Rudiments of Physiology, by Dr. Lewins, pt. 3, p. 71, Edinb., 1837
7 Travels, p. 281.
8 Medico-Chirurgical Transactions, vii. 157.

size of the buttocks arose from a vast mass of fat, interposed between the integuments and muscles, which equalled four fingers' breadth in thickness. It is singular, that, according to the statement of this female, which is corroborated by the testimony of Sir John Barrow, the deposition does not take place till the first pregnancy. Pallas[1] has described a variety of sheep—*ovis steatopyga* or "fat buttocked"—which is reared in immense flocks by the pastoral tribes of Asia. In it, a large mass of fat covers the nates and occupies the place of the tail. The protuberance is smooth beneath, and resembles a double hemisphere, when viewed behind,—the os coccygis or rump-bone being perceptible to the touch in the notch between the two. They consist merely of fat; and, when very large, shake in walking like the buttocks of the female Bosjesman. Mr. Lawrence[2] remarks, that there are herds of sheep in Persia, Syria, Palestine, and some parts of Africa, in which the tail is not wanting as in *ovis steatopyga*, but retains its usual length, and becomes loaded with fat.

In the view of Liebig,[3] the abnormous condition, which causes an undue deposition of fat in the animal body, depends on a disproportion between the quantity of carbon in the food, and that of the oxygen absorbed by the skin and lungs. In the normal condition, the quantity of carbon given out is exactly equal to that which is taken in the food, and the body experiences no increase of weight from the accumulation of substances containing much carbon and no nitrogen; but if the supply of highly carbonized food be increased, then the normal state can only be preserved, by exercise and labour, through which the waste of the body is increased, and the supply of oxygen accumulated in the same proportion. The production of fat, Liebig maintains, is always a consequence of a deficient supply of oxygen; for oxygen is absolutely indispensable for the dissipation of the excess of carbon in the food. "This excess of carbon, deposited in the form of fat, is never seen in the Bedouin or in the Arab of the desert, who exhibits with pride to the traveller his lean, muscular, sinewy limbs, altogether free from fat; but in prisons and jails it appears as a puffiness in the inmates, fed, as they are, on a poor and scanty diet: it appears in the sedentary females of oriental countries; and is produced under the well-known conditions of fattening of domestic animals." In accordance, too, with his views of animal temperature, already referred to, Liebig considers that in the formation of fat there is a new source of heat. The oxygen set free in the action is given out in combination with carbon and hydrogen; and whether this carbon and hydrogen proceed from the substance that yields the oxygen, or from other compounds, still there must have been generated by the formation of carbonic acid or water as much heat as if an equal weight of carbon or hydrogen had been burned in air or in oxygen gas.

Whether the view of Liebig be admitted or not, it is certain that the circumstances, which favour obesity, are absence of activity and excite-

[1] Spicilegia Zoologica, fasc. xi. p. 63. Also, Erman, Travels in Siberia, Amer. edit., Philad., 1850.

[2] Lectures on Physiology, Zoology, &c., p. 427, London, 1819.

[3] Animal Chemistry, Webster's edit., p. 85, Cambridge, Mass., 1842.

ment of all kinds; hence, for the purpose of fattening animals in rural economy, they are kept in entire darkness, to deprive them of the stimulus of light, and encourage sleep and muscular inactivity. Castration—by abolishing one kind of excitability—and the time of life at which the generative functions cease to be exerted, especially in the female, are favourable to the same result.

b. Marrow.

A fluid, essentially resembling fat, is found in the cavity of long bones, in the spongy tissue of short bones, and in the areolæ of bones of every kind. This is the *marrow—medulla ossium.* The secretory organ is the very delicate membrane, which is perceptible in the interior of the long bones, lining the medullary cavity, and sending prolongations into the compact substance, and others internally, which form septa and spaces for the reception of the marrow. The cells, thus formed, are distinct from each other. From the observations of Mr. Howship,[1] it would seem probable, that the oil of bones is deposited in longitudinal canals, that pass through the solid substance of the bone, and through which its vessels are transmitted. This *oil of bones* is the *marrow* of the compact structure, the latter term being generally restricted to the secretion when contained in the cavities of long bones; that which exists in the spongy substance being termed, by some writers, the *medullary juice.* The *medullary membrane*, called also the *internal periosteum*, consists chiefly of bloodvessels ramifying on an extremely delicate areolar tissue, in which nerves may likewise be traced.

Berzelius examined marrow obtained from the thigh-bone of an ox, and found it consist of the following constituents:—pure adipous matter, 96; skins and bloodvessels, 1; albumen, gelatin, extractive, peculiar matter, and water, 3.

The marrow is one of the corporeal components, of whose use we can scarcely offer a plausible conjecture. It has been supposed to render the bones less brittle; but this is not correct, as those of the fœtus, which contain little or no marrow, are less so than those of the adult; whilst those of old persons, in whom the medullary cavity is large, are more brittle than those of the adult. It is possible that it may be placed in the cavities of bones,—which would otherwise be so many vacant spaces,—to serve the general purposes of fat, when required by the system. The other hypotheses that have been entertained on the subject are not deserving of notice.

5. *Exhalation of the Pigment Membrane.*

The nature of the exhalation, which constitutes the colouring matter of the rete mucosum, has already engaged attention, when treating of the skin under the Sense of Touch. It is presumed to be exhaled by the vessels of the skin, and to be deposited beneath the cuticle, so as to communicate the colours that characterize the different races. Such are regarded as the secretory organs by most anatomists and physiolo-

[1] Medico-Chirurg. Trans., vii. 393.

gists; but M. Gaultier,[1] whose researches into the intimate constitution of the skin have gained him much celebrity, is of opinion, that it is furnished by the bulbs of the hair; and he assigns, as reasons for this belief, that the negro, in whom it is abundant, has short hair; that the female, whose hair is more beautiful and abundant than that of the male, has the fairest skin; and that when he applied blisters to the skin of the negro, he saw the colouring matter oozing from the bulbs and deposited at the surface of the rete mucosum. But the views of modern anatomists on the corpus mucosum have been given already.[2]

The composition of this pigment cannot be determined with precision, owing to its quantity being too small to admit of examination. Chlorine deprives it of its black hue, and renders it yellow. A negro, by keeping his foot for some time in water impregnated with this gas, deprived it of its colour, and rendered it nearly white; but in a few days the black colour returned with its former intensity. The experiment was made with similar results on the fingers. Blumenbach[3] thought, that the mucous pigment was formed chiefly of carbon; and the notion has received favour with many.

The colour, according to Henle and others, is owing to pigment cells, of which the pigmentum nigrum of the eye is wholly composed. They are considered to exhibit, usually, the original form of the cell with little alteration. On the choroid coat they form a kind of pavement, and have somewhat of a polyhedral shape. In the human skin, they are scattered through the ordinary epidermic cells, and the colour of the skin is determined by that of their contents. Krause,[4] however, denies that the colour of the cuticle of the Ethiopian depends on pigment cells, like those of the pigmentum nigrum. It is owing chiefly, he says, to the colour of the proper nuclei and cells of the epidermis. There are, indeed, some few pigment cells mingled with the proper cells of the middle and superficial layers of the epidermis; but they are distinguishable from those of the pigmentum nigrum by containing far fewer pigment granules, and by having always a dark, not a clear, nucleus. The colour depends especially on the dark or almost black-brown colour of the nuclei, whether free in the deep layers of epidermis or surrounded by cells. They have dark nucleoli; sharp outlines; appear only very obscurely granular, and cannot be broken into smaller pigment granules. The cells surrounding them may be seen in the deeper layers: they, also, are uniformly dark, although less so than the nuclei. In the middle and superficial layers, the nuclei, as long as they can be seen, are still dark; the cells are much paler, but brownish and darker than in the corresponding layers in uncoloured persons.

Pigment granules are amongst the most minute structures of the body, being not more than $\frac{1}{20000}$th of an inch in their largest diameter, and about one-fourth as much in thickness.

[1] Recherches sur l'Organisation de la Peau de l'Homme, &c., Paris, 1809 and 1811.

[2] See Vol. i. p. 124.

[3] Instit. Physiol., § 274; and Elliotson's translation, 4th edit., Lond., 1828.

[4] Art. Haut, in Wagner's Handwörterbuch der Physiologie, 7 Lief., s. 108, Braunschweig, 1844.

The uses of the pigment of the skin—as well as of that which lines the choroid coat of the eye, the posterior surface of the iris, and the ciliary processes—are detailed in other places.

6. *Exhalation of Areolar Capsules.*

Under this term, M. Adelon[1] has included different recrementitial secretions effected within the organs of sense, or in parenchymatous structures,—as the aqueous, crystalline, and vitreous humours of the eye, and the liquor of Cutugno, all of which have already engaged attention; the exhalation of a kind of albuminous, reddish, or whitish fluid into the interior of the lymphatic ganglions, and into the organs, called by M. Chaussier, *glandiform ganglions*, and by M. Béclard, *sanguineous ganglions;*—namely, the thymus, thyroid, supra-renal capsules, and spleen. We know but little, however, of the fluids formed in these parts: they have never been analyzed, and their uses are unknown.

7. *Vascular Exhalation.*

A fluid is exhaled from the inner or serous coat of the arterial, venous, and lymphatic vessels. It must be serous, and its use doubtless is to lubricate the interior of the vessel, and prevent adhesion between it and the fluid circulating within it.

B. EXTERNAL EXHALATIONS.

1. *Exhalation of Mucous Membranes—General and Pulmonary.*

The mucous membranes, like the skin, which they so strongly resemble in their structure, functions, and diseases, exhale a similar transpiratory fluid. This has not been subjected to chemical examination. It is, indeed, almost impracticable to separate it from the follicular secretions of the same membrane; and from the extraneous substances almost always in contact with it. It is probably, however, similar to the fluid of the cutaneous and pulmonary depurations, both in character and use.

The pulmonary transpiration, to which allusion has so often been made, bears a striking analogy to the cutaneous. Sir B. Brodie and M. Magendie, from the examination of cases of fistulous opening into the trachea, deny that it comes from the lungs, believing it to be formed by the moist mucous lining of the nose, throat, &c.; but this view has been disproved by Paoli and Regnoli, in the case of a young female, whose trachea had been opened, and in whom, at the temperature of 39° Fahr., watery vapour was distinctly expired through the canula. Mojon[2] strangely supposes the vapour of the breath to be a watery fluid secreted by the thyroid gland, and suspended in the respired air, its volatility being caused by the presence of caloric. At one time, it was universally believed to be owing to the combustion of the hydrogen and carbon given off from the lungs; but we have elsewhere shown, that no such combustion occurs there; and besides, the exhalation takes place when gases containing no oxygen are respired by animals. It is

[1] Physiologie de l'Homme, 2de édit., tom. iii. 483, Paris, 1829.
[2] Leggi Fisiologiche, &c., translated by Skene, p. 76, Lond., 1827.

now almost universally admitted to be exhaled into the air-cells of the lungs from the pulmonary artery chiefly; but partly from the bronchial arteries distributed to the mucous membrane of the air-passages. Much of the vapour, Dr. Prout conceives, is derived from the chyle in its passage through the lungs; and thus, he considers, the weak and delicate albumen of the chyle is converted into the strong and perfect albumen of the blood.

The air of expiration, according to Valentin[1] and Brunner, appears saturated with it, so that, as they have remarked, the quantity of vapour exhaled may be estimated by subtracting the quantity contained in the atmospheric air expired from the quantity, which, at the same barometric pressure, would saturate the same atmospheric air at the temperature of 99·5°—the general temperature of the air of expiration. On the other hand, if the quantity of watery vapour in the expired air be estimated, the quantity of the air itself may thence be accurately determined—being as much as that quantity of watery vapour would saturate at the ascertained temperature and barometric pressure. It has not been established, however, that the expired air is saturated with moisture.

Sundry interesting experiments have been made on this exhalation by Magendie, Milne Edwards, Breschet, and others. If water be injected into the pulmonary artery, it passes into the air-cells in myriads of almost imperceptible drops, and mixes with the air contained in them. M. Magendie[3] found, that its quantity might be augmented at pleasure on living animals, by injecting distilled water, at a temperature approaching that of the body, into the venous system. He injected into the veins of a small dog a considerable amount of water. The animal was at first in a state of real plethora—the vessels being so much distended that it could scarcely move; but in a few minutes the respiration became manifestly hurried, and a large quantity of fluid was discharged from the mouth, the source of which appeared evidently to be the pulmonary transpiration greatly augmented.

But not only is the aqueous portion of the blood exhaled in this manner, experiment shows, that many substances introduced into the veins by absorption, or by direct injection, issue from the lungs. Weak alcohol, a solution of camphor, ether, and other odorous substances, when thrown into the cavity of the peritoneum or elsewhere, were found, by M. Magendie, to be speedily absorbed by the veins, and conveyed to the lungs, where they transuded into the bronchial cells, and were recognised in the expired air by their smell. Phosphorus, when injected, exhibited this transmission in a singular and evident manner. M. Magendie,[4] on the suggestion of M. Armand de Montgarny, "a young physician," he remarks, "of much merit," now no more, injected into the crural vein of a dog, half an ounce of oil, in which phosphorus had been dissolved: scarcely had he finished the injection, before the animal sent through the nostrils clouds of a thick white

[1] Lehrbuch der Physiologie des Menschen, i. 547, Braunschweig, 1844.

[2] Dr. John Reid, art. Respiration, Cyclop. of Anat. and Phys., pt. xxxii. p. 345, Lond., Aug., 1848.

[3] Précis, &c., ii. 346.

[4] Ibid., ii. 348.

vapour, which was phosphoric acid. When the experiment was made in the dark, these clouds were luminous. M. Tiedemann[1] injected a drachm of the expressed juice of garlic into a vein of the thigh of a middle-sized dog: in the space of three seconds the breath smelt strongly of garlic. When spirit of wine was injected, the exhaled vapour was recognised when the injection was scarcely over.

MM. Breschet and Milne Edwards[2] made several experiments for the purpose of discovering why the pulmonary transpiration expels so promptly the different gases and liquid substances received into the blood. Considering properly, that exhalation differs only from absorption in taking place in an inverse direction, these gentlemen conjectured, that it ought to be accelerated by every force, that would attract the fluids from within to without; and such a force they conceive inspiration to be, which, in their view, solicits the fluids of the economy to the lungs, in the same mechanical manner as it occasions the entrance of air into the air-cells. In support of this view they adduce the following experiments. To the trachea of a dog a pipe, communicating with a bellows, was adapted, and the thorax was largely opened. Natural respiration was immediately suspended; but artificial respiration was kept up by means of the bellows. The surface of the air-cells was, in this way, constantly subjected to the same pressure, there being no longer diminished pressure during inspiration, as when the thorax is sound, and the animal breathing naturally. Six grains of camphorated spirit were now injected into the peritoneum; and, at the same time, a similar quantity in another dog, whose respiration was natural. In the course of from three to six minutes, the odorous substance was detected in the pulmonary transpiration of the latter; but in the other it was never manifested. They now exposed in the first animal a part of the muscles of the abdomen, and applied a cupping-glass to it; when the smell of the camphor speedily appeared at the cupped surface. Their conclusion was, that the pulmonary surface, having ceased to be subjected to the suction force of the chest during inspiration, exhalation was arrested, whilst that of the skin was developed as soon as an action of aspiration was exerted upon it by the cupping-glass.

Into the crural veins of two dogs,—one of which breathed naturally, and the other was circumstanced as in the last experiment, they injected essential oil of turpentine. In the first of these, the substance was soon apparent in the pulmonary transpiration; and, on opening the body, it was discovered, that the turpentine had impregnated the lung and pleura much more strongly than the other tissues. In the other animal, on the contrary, the odour of the turpentine was scarcely apparent in the vapour of the lungs; and on dissection, it was not found in greater quantity in the lungs than in other tissues;—in the pleura, for instance, than in the peritoneum.

From the results of these experiments, MM. Breschet and Edwards conclude, that each inspiratory movement constitutes a kind of suction,

[1] Tiedemann und Treviranus, Zeitschrift für Physiologie, Band. v. H. ii.; cited in British and Foreign Medical Review, i. 241, Lond., 1836.

[2] Recherches Expérimentales sur l'Exhalation Pulmonaire, Paris, 1826.

which attracts the blood to the lungs; and causes the ejection of the liquid and gaseous substances which are mingled with that fluid, through the pulmonary surface, more than through the other exhalant surfaces of the body. In their experiments, these gentlemen did not find, that exhalation was effected with equal readiness in every part of the surface, when the cupping-glass was applied in the mode that has been mentioned. The skin of the thigh, for example, did not indicate the odour of camphorated alcohol as did that of the region of the stomach.

The chemical composition of the pulmonary transpiration is probably nearly identical with that of the sweat; appearing to consist of water, holding in solution, perhaps, some saline and albuminous matter; but our information on this matter, derived from the chemist, is not precise. M. Collard de Martigny's[1] experiments make it consist, in 1000 parts,—of water 907, carbonic acid 90; animal matter—the nature of which he was unable to determine—3. M. Chaussier found, that by keeping a portion of it in a close vessel exposed to an elevated temperature, a very evident putrid odour was exhaled on opening the vessel. This could only have arisen from the existence of nitrogenized matter in it.

The pulmonary transpiration being liable to all the modifications which affect the cutaneous, it is not surprising, that we should meet with so much discordance in the estimates of different individuals, regarding its quantity in a given time. Hales[2] valued it at 20 ounces in the twenty-four hours: Sanctorius,[3] Menzies,[4] and Dr. William Wood,[5] at 6 ounces; Mr. Abernethy[6] at 9 ounces; MM. Lavoisier and Séguin[7] at $17\frac{1}{2}$ ounces *poids de marc;* Dr. Thomson[8] at 19 ounces, Dr. Dalton at from 1 pound $8\frac{3}{4}$ ounces,[9] to $20\frac{1}{2}$ ounces avoirdupois,[10] and Dr. Carpenter[11] at from 16 to 20 ounces, and Kirkes and Paget[12] at from 6 to 27 ounces. The uses it serves in the animal economy are identical with those of the cutaneous transpiration. It is essentially depuratory. Experiments, some of which have been detailed, have sufficiently shown, that volatile substances introduced in any way into the circulatory system, if not adapted for the formation of arterial blood, are rapidly exhaled into the bronchial tubes. Independently, therefore, of the lungs being the great organs of respiration, they play a most important part in the economy, by throwing off those substances, that might be injurious, if retained.

2. *Menstrual Exhalation.*

The secretion of the menstrual fluid, which is a true sanguineous exhalation from the vessels of the uterus, will fall more appropriately under consideration when treating of the functions of reproduction.

[1] Magendie's Journal de Physiologie, x. 111.
[2] Statical Essays, ii. 322, Lond., 1767.
[3] Medicina Statica, Aphor. v.
[4] Dissertation on Respiration, p. 54, Edinb., 1796.
[5] Essay on the Structure, &c., of the Skin, Edinb., 1832.
[6] Surgical and Physiol. Essays, p. 141, Lond., 1793.
[7] Mém. de la Société Royale de Médecine, pour 1782–3; Annal. de Chimie, v. 264; and Mém. de l'Acad. des Sciences, pour 1789.
[8] System of Chemistry, vol. iv.
[9] Manchester Memoirs, 2d series, ii. 29.
[10] Ibid., vol. v.
[11] Human Physiology, § 549, Lond., 1842.
[12] Manual of Physiology, Amer. edit., p. 139, Philad., 1849.

3. *Gaseous Exhalation.*

The secretion of air from the bloodvessels is not so manifest as in the case of the exhalations thus far considered; but if we regard, with many, the separation of carbonic acid from the blood as a secretion, it is one of the most extensive and important in the animal economy. Gases are perpetually received into the vessels of the lungs, and to a certain degree elsewhere, whilst carbonic acid—as we have seen, under the function of Respiration—is constantly exhaled. Moreover, in the swim-bladders of fishes an unequivocal case of gaseous secretion is presented; for many of these have no communication whatever by duct or otherwise with any outlet of the body. In the order Pharyngognathi of Müller, which includes the family of the saury-pike and others—in Anacanthini, including the cod and plaice; in Acanthopteri, including the perch, gurnard, mullet, mackerel, and others; in the Plectognathi of Cuvier, including the globe fish; and in Lophobranchii of the same naturalist, which includes the sea horse and pipe fish,—a characteristic is the possession of a swim bladder without an air duct. In these cases, there can be no question of the secretion of air; and accordingly such a secretion has been admitted by physiologists.[1] It may account for the copious developement of air in the intestinal canal, as has been suggested elsewhere;[2] and for the production of many of the pneumatoses, which are so difficult of explanation under any other view. The last subject has, however, received the author's attention in another work.[3]

II. FOLLICULAR SECRETIONS.

The *follicular secretions* must, of necessity, be effected from the skin or the mucous membranes, inasmuch as follicles or crypts are met with there only. They may, therefore, be divided into two classes;—1st, the *follicular secretions of mucous membranes;* and 2dly, the *follicular secretions of the skin.*

1. *Follicular Secretion of Mucous Membranes.*

The whole extent of the mucous membranes lining the alimentary canal, air-passages, and urinary and genital organs, is the seat of a secretion, the product of which has received, in the abstract, the name of *mucus;* although it differs somewhat according to the situation and character of the particular follicles whence it proceeds. Still, essentially, the structure, functions, and products of all mucous membranes are the same (see vol. i. p. 131). Such is the general sentiment. M. Donné,[4] however, ranges the different mucous membranes in three great divisions—according to their microscopical characters, the chemical reaction of their mucus, and the structure of the epithelium. His *first* division comprises those membranes that are analogous to the skin,—in other words, that secrete an acid fluid, which contain, under the form of pelli-

[1] John Hunter, Observations on Certain Parts of the Animal Economy, with Notes by Prof. Owen, Amer. edit., p. 127, Philad., 1840. J. Vogel, The Pathological Anatomy of the Human Body, by Dr. Day, p. 31, London, 1847; and Prof. Owen, Lectures on the Comparative Anatomy and Physiology of the Vertebrate Animals, p. 272, Lond., 1846.

[2] Vol. i. p. 615.

[3] Practice of Medicine, 3d edit., i. 172, Philad., 1848.

[4] Cours de Microscopie, p. 143, Paris, 1844.

cles, or scales, the product of the desquamation of the epidermis. They are, in reality, reflections of the outer skin, and in no respect deserve the name of mucous membranes. The vaginal mucous membrane is one of these, being a mere reflection of the outer skin, and possessing its principal properties. It secretes a mucus, which is always acid; strongly reddening litmus paper, and filled with soft, flattened lamellæ, or rather cells, like the epidermic vesicles of the skin. In regard to its physiological properties, this membrane, like the skin, is endowed with exquisite sensibility; it is scarcely ever the seat of hemorrhage, and ulcerates less readily than mucous membranes properly so called. The membranes with acid mucus and epidermic vesicles never, he says, exhibit any epidermic cells. The *second* division comprises the "true mucous membranes." They differ from the skin in every respect,—both by the nature of their epithelium, and the chemical reaction of their secretion, which is always alkaline. It is viscid, and, instead of exhibiting under the microscope the epidermic lamellæ or cellules, mentioned above, it presents only mucous globules, whose structure, properties, and origin are entirely different. These membranes, of which the bronchial mucous membrane may be taken as the type, ulcerate readily; are the seat of hemorrhages, and do not possess tactile sensibility like the skin. To these belong the vibratile organs or cilia.

These two orders of membranes, according to M. Donné, are found approximated, and almost confounded, although still preserving their distinct characters, in the vagina and neck of the uterus,—the one secreting a creamy, not ropy, always acid mucus; and presenting, under the microscope, large epidermic cellules; the other furnishing a glairy, ropy mucus, constantly alkaline, and containing mucous globules much smaller than epidermic cells, and of a structure and composition wholly different. The *third* division comprises a class intermediate between the two others, constituted by parts which participate in the organization of skin and mucous membranes, through surfaces which have not yet entirely lost the qualities of the external membrane, and already possess some of those of the internal or true mucous membranes. Such are the orifices where the skin does not terminate suddenly, but becomes gradually transformed into mucous membrane, as at the mouth, nose, anus, &c. These parts secrete a mucus, which M. Donné terms *mixed;* in this are found combined the characters of the two already mentioned, with a predominance of the one or the other, according as the properties of the skin, or those of the mucous membranes, prevail. The mucus of the mouth he regards as an example of the intermediate species.[1]

In the history of the different functions, in which certain of the mucous membranes are concerned, the uses of the secretion have been detailed; and in those functions, that will hereafter have to engage attention, in which other mucous membranes are concerned, its uses will fall more conveniently under notice. But few points will, therefore, require explanation at present.

The mucus secreted by the nasal follicles seems alone to have been

[1] See, on the structure, relations, and offices of the Mucous Membranes, Mr. Bowman, art. Mucous Membrane, in Cyclop. of Anat. and Physiol., Parts xxiii. and xxiv., Lond., 1842.

subjected to chemical analysis. MM. Fourcroy and Vauquelin[1] found it composed of the same ingredients as tears. According to the analysis of Berzelius,[2] its contents are as follows:—water, 933·7; mucus, 53·3; chlorides of potassium and sodium, 5·6; lactate of soda with animal matter, 3·0; soda, 0·9; albumen and animal matter, soluble in water, but insoluble in alcohol, with a trace of phosphate of soda, 3·5. Dr. G. O. Rees[3] considers mucus to be a compound of albumen in a state of close combination with alkaline salts, and probably free alkali; and he affirms, that the artificial compound formed by the addition of alkalies and neutral salts to albuminous matter is essentially the same as mucus.

According to M. Raspail,[4] mucus is the product of the healthy and daily disorganization or wear and tear of mucous membranes. Every mucous membrane, he affirms, exfoliates in organized layers, and is thrown off, more or less, in this form; but the serous membranes either do not exfoliate, or their exfoliation (*excoriation*) is reduced to a liquid state to be again absorbed by the organs. This, however—like many of M. Raspail's speculations—is a generalization that does not appear to be warranted by facts: the slightest examination, indeed, exhibits, that the general physical character of mucus is very different from that of the membranes which form it: still, when examined by a microscope of high magnifying power, it presents here and there, appearances of shreds similar to those described by M. Raspail. These have been considered by recent histologists detached epithelium cells, with granulated globular particles, which are esteemed to be characteristic of the secretion from the surface of mucous membranes.[5]

Although mucus is classed as a follicular secretion, it would seem to be formed in mucous membranes in which no follicles can be detected, as in those lining the frontal and other sinuses of the cranium. M. Mandl,[6]—who first stated the belief in the identity in structure of the globules of mucus and pus and the red corpuscles of the blood,—describes mucus as composed of a viscid liquid in which are swimming, besides lamellæ of epithelium, special elements, which he calls *globules of mucus*. These are of two kinds,—the one consisting *of mammillated corpuscles*, 0·005 to 0·006 of a *millimètre* in diameter; the other, from 0·01 to 0·02 of a *millimètre* in diameter,—the latter being true cells, composed of an envelope and a nucleus.

The great use of mucus, wherever met with, is to lubricate the surface on which it is poured. Experiments, however, by Oesterlen[7] have proved the influence of the layer of mucus, which lines the digestive canal, in retarding both the imbibition of fluids inclosed within the canal, and the permeation of fluids by endosmose. The passage of fluid into, or through, the mucous membrane of the intestines was, in

[1] Journal de Physique, xxxix. 359.

[2] Medico-Chirurg. Transactions, tom. iii.; also, Thomson, Chemistry of Animal Bodies, p. 507, Edinb., 1843.

[3] Cyclop. of Anat. and Physiol., P. xxiii. p. 484, April, 1842.

[4] Chimie Organique, p. 246, and p. 504, Paris, 1832.

[5] For the different forms of mucus, see Donné, op. cit., p. 145.

[6] Manuel d'Anatomie Générale, p. 478, Paris, 1843.

[7] Beiträge zur Physiologie des Gesunden und Kranken Organismus, s. 245, Jena, 1843.

many cases, more than twice as rapid when the mucus had been removed as when still adherent.

a. Secretion of the Peyerian Glands.

The morphology and functions of the Peyerian follicles or glands have been investigated elsewhere.[1] They are peculiar in having no outlets; the fluid elaborated by them from the blood being poured, by the bursting of the formative cells, on the mucous surface of the intestinal canal.

b. Secretion of the Ovaria.

In many respects the secretion of the ovaria—the formation of ova—is accomplished like that of the Peyerian glands. Like them, the follicles of De Graaf are devoid of outlet; and the secretion has to make its way to the surface of the ovary and be discharged,—the Fallopian tube receiving it, and acting as an excretory duct. The mode in which this is accomplished will fall more appropriately under consideration, when the functions of Reproduction are investigated.

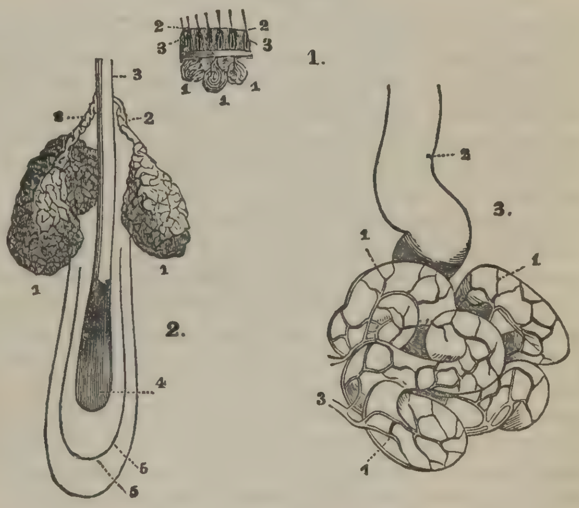
2. *Follicular Secretion of the Skin.*

This is the sebaceous and micaceous humour, observed in the skin of the cranium, and in that of the pavilion of the ear. It is, also, the humour, which occasionally presents the appearance of small worms beneath the skin of the face, when it is forced through the external aperture of the follicle; and when exposed to the air causes the black spots sometimes observable on the face.

The following were found by Esenbeck[2] to be its constituents: salt, 24·2; osmazome, with traces of oil, 12·6; watery extracts, 11·6; albumen and casein, 24·2; carbonate of lime, 2·1; phosphate of lime 20·0; carbonate of magnesia, 1·6; acetate of soda, and chloride of sodium, traces.

The cutaneous or miliary follicles or glands were refer-

Fig. 326.



Sebaceous or Oil Glands and Ceruminous Glands.

1. Section of skin, magnified three diameters. 2, 2. Hairs. 3, 3. Superficial sebaceous glands. 1, 1. Larger and deeper-seated glands by which the cerumen appears to be secreted. 3. A ceruminous gland more largely magnified, formed of convoluted tube 1, forming excretory duct 2. 3. A small vessel, and its branches. 2. A hair from meatus auditorius, perforating epidermis at 3, and at 4, contained within its double follicle, 5, 5. 1, 1. Sebaceous follicles of hair with their excretory ducts. (Wagner.)

[1] Vol. i. p. 532.

[2] V. Bruns, Lehrbuch der Physiologie des Menschen, s. 353, Braunschweig, 1841.

red to in describing the anatomy of the common integument.[1] At times, they are simple crypts, formed merely by an inversion of the common integument; at others, more complicated but still a like inversion; and they commonly open into channels by which the hairs issue. (Figs. 44 and 326, 2.)

Fig. 327.

Cutaneous Follicles or Glands of the Axilla, magnified one-third. (Horner.)

In certain parts of the skin, they are more numerous than in others. Mr. Rainey — as hereafter remarked[2] — was unable to detect them in the palms of the hands and soles of the feet. Their appearance in the axilla of the negro has been described by Professor Horner.[3] Their granular or composite character in the axilla, he thinks, is sufficiently evident; but the point is yet to be settled, whether their excretory ducts have the tortuous arrangement of those of the ceruminous glands, or whether they be branched and racemose, like those of the salivary. Mr. Hassall[4] affirms, that they are similar in organization to the sudoriparous glands, but much larger.

The secretion from the different cutaneous follicles differs, probably, according to the different character and arrangement of animal membrane from which the cells that form it are developed. There is, certainly, a marked difference between the fluids secreted in the axilla, groin, prepuce, feet, &c., each appearing to have its characteristic odour; although a part of this may be owing to changes occurring in the matter of secretion by retention in parts to which the free access of air is prevented. The cutaneous or miliary glands, depicted by Dr. Horner, are considered by him to be the *glandulæ odoriferæ* of the axilla. In many animals odorous secretions of a similar character are formed by special organs; but whether the scent peculiar to animals and to races is thus secreted is canvassed elsewhere,[5] and must be regarded as somewhat unsettled.

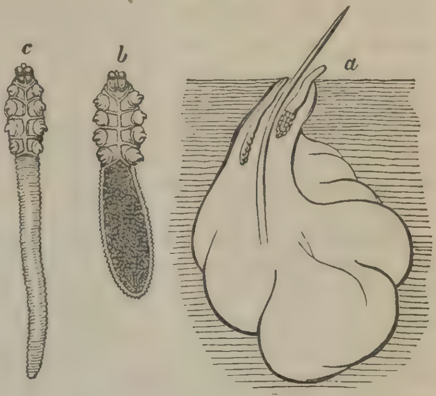
The cerumen is, likewise, a follicular secretion, as well as the whitish,

[1] Vol. i. p. 126.
[2] Page 292.
[3] American Journal of the Medical Sciences, for January, 1846, p. 13.
[4] The Microscopic Anatomy of the Human Body, Part xiii. p. 426, Lond., 1848.
[5] P. 294.

odorous and fatty matter—*smegma*—which forms under the prepuce of the male, and in the external parts of the female, where cleanliness is disregarded. The humour of Meibomius is also follicular, as well as that of the caruncula lachrymalis of the crypts around the base of the nipple, &c.

The use of these secretions is to favour the functions of the parts over which they are distributed. That which is secreted from the skin is spread over the epidermis, hair, &c., giving suppleness and elasticity to the parts; rendering the surface smooth and polished, and thus obviating the evils of abrasion that might otherwise arise. It is also conceived, that its unctuous nature may render the parts less permeable to humidity.

Fig. 328.



Entozoa from the Sebaceous Follicles.

a. Two seen in their ordinary position in the orifice of one of the sebaceous follicles of the scalp. *b*. Short variety. *c*. Long variety.

In the ducts of the sebaceous follicles, a parasite was discovered by M. Simon, of Berlin;[1] which has been minutely described by Mr. Erasmus Wilson,[2] Professor Vogel,[3] Messrs. Todd and Bowman,[4] and Professor Owen.[5] It is the *Acarus folliculorum* of Simon, *Demodex folliculorum* of Owen, and *Steatozoon folliculorum* of Mr. Wilson. By him two chief varieties of the adult animal are depicted. These are mainly distinguished by their length—the one measuring from the $\frac{1}{100}$th to the $\frac{1}{45}$th, the other from the $\frac{1}{100}$th to the $\frac{1}{109}$th of an inch.

The marginal figure represents them as found by Messrs. Todd and Bowman in a sebaceous follicle of the scalp. They do not appear to be of any physiological or pathological importance.

III. GLANDULAR SECRETIONS.

The glandular secretions are seven in number; the transpiration, tears, saliva, pancreatic juice, bile, urine, sperm, and milk.

1. *The Transpiratory Secretion.*

A transparent fluid is constantly exhaled from the skin, which is generally invisible in consequence of its being converted into vapour as soon as it reaches the surface; but, at other times, owing to augmenta-

[1] Müller's Archiv., s. 218, 1842.

[2] On Diseases of the Skin, 2d Amer. edit., p. 424, Philad., 1847; and in Philosophical Transactions for 1844.

[3] The Pathological Anatomy of the Human Body; translated by Dr. Day, p. 453, Lond., 1847.

[4] The Physiological Anatomy and Physiology of Man, p. 425, Lond., 1845.

[5] Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals, p. 251, Lond., 1843.

tion of the secretion, or to the air being loaded with humidity, it is apparent on the surface of the body. When invisible, it is called *insensible transpiration* or *perspiration;* when perceptible, *sweat.* In the state of health, according to M. Thénard,[1] this fluid reddens litmus paper; yet the taste is rather saline—resembling that of common salt —than acid. Wagner,[2] indeed, affirms that it generally shows alkaline reaction; and, at other times, does not affect vegetable blues; but the sweat of many parts of the body,—the armpits for example,—is said always to react like an alkali. Allusion has already been made to the views of M. Donné,[3] who considers, that the external, and the internal alkaline membranes of the human body represent the two poles of a pile, the electrical effects of which are appreciable by the galvanometer.

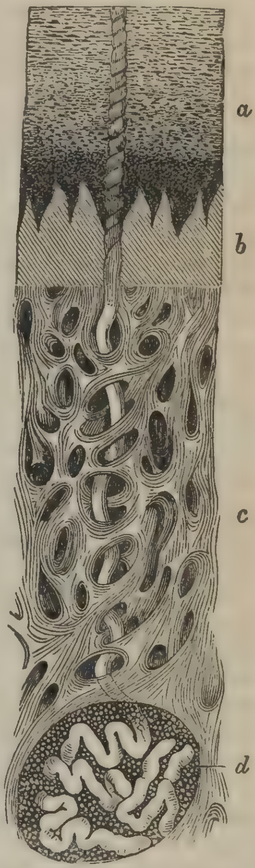
The smell of the perspiration is peculiar, and when concentrated, and especially when subjected to distillation, becomes almost insupportable. The fluid is composed, according to M. Thénard, of much water, a small quantity of acetic acid, chloride of sodium, and perhaps of potassium, a very little earthy phosphate, a trace of oxide of iron, and an inappreciable quantity of animal matter. Berzelius[4] regards it as water holding in solution chlorides of potassium and sodium, lactic acid, lactate of soda, and a little animal matter; Anselmino,[5] as consisting of a solution of osmazome, chlorides of sodium and calcium, acetic acid, and an alkaline acetate, salivary matter, sulphates of soda and potassa, and calcareous salts, with mucus, albumen, sebaceous humour, and gelatin in variable proportions; and M. Raspail[6] looks upon it as an acid product of the disorganization of the skin. The solid constituents, according to Simon,[7] are a mixture of salts and extractive matters, of which the latter preponderate: the principal ingredient of the salts is chloride of sodium. From what he admits to be superficial and merely qualitative investigations, he considers he has established the existence in normal sweat, of—*First.* Substances soluble in ether; traces of fat, sometimes including butyric acid. *Secondly.* Substances soluble in alcohol; alcohol extract; free lactic or acetic acid; chloride of sodium; lactates and acetates of potassa and soda; lactate or chlorohydrate of ammonia. *Thirdly.* Substances soluble in water; water—extract; phosphate of lime, and occasionally an alkaline sulphate; and, *fourthly.* Substances insoluble in water; desquamated epithelium; and—after the removal of the free lactic acid by alcohol —phosphate of lime with a little peroxide of iron. In the solid matter urea was detected by Landerer.[8]

After evaporation upon a clean glass plate, fragments of epidermic cells are generally observed in it, and crystals are left behind, which

[1] Traité de Chimie, tom. iii.
[2] Elements of Physiology, by R. Willis, § 204, Lond., 1842.
[3] Journal Hebdomad., Février, 1834.
[4] Medico-Chir. Trans., iii. 256.
[5] Lepelletier, Physiologie Médicale et Philosophique, ii. 452, Paris, 1832.
[6] Chimie Organique, p. 505, Paris, 1832.
[7] Animal Chemistry, Sydenham Society edit., ii. 101, Lond., 1846.
[8] G. O. Rees, art. Sweat, Cyclopædia of Anatomy and Physiology, pt. xxxvii. p. 844, Lond., October, 1849.

are those of its contained salts. With great care to avoid admixture, Krause[1] collected a small quantity of pure cutaneous perspiration from the palm of the hand, where there are no sebaceous follicles. The fluid yielded, with boiling ether, some small globules of oil and crystals of margarin. It was acid, but after twenty-four hours became alkaline, by the developement of ammonia. In another experiment, he found, that the tissue of the epidermis contains a fatty substance independently of the fatty matter secreted on its surface.

Fig. 329.



Vertical Section of the Sole.

a. Cuticle; the deep layers (rete mucosum) more coloured than the upper, and their particles rounded; the superficial layers more and more scaly. *b.* Papillary structure. *c.* Cutis. *d.* Sweat-gland, lying in a cavity on the deep surface of the skin, and imbedded in globules of fat. Its duct is seen passing to the surface. Magnified 40 diameters. (Todd and Bowman.)

In a memoir presented to the *Académie Royale des Sciences* of Paris, MM. Breschet and Roussel de Vauzème first clearly showed, that there exists in the skin an apparatus for the secretion of the sweat, consisting of a glandular parenchyma, which secretes the liquid, and of ducts, which pour it on the surface of the body. These ducts are arranged spirally, and open very obliquely under the scale of the epidermis. To this apparatus they applied the epithet "*diapnogenous*:" and called the ducts "*sudoriferous* or *hidrophorous*."[2]

Each *sudoriparous gland* consists of a coil or excretory duct surrounded by bloodvessels, and imbedded in fat vesicles. Thence the duct passes in the manner represented in the marginal figure, towards the surface, and opens on the epidermis by an oblique valve-like aperture. The excretory duct is lined by epithelium, which is a prolongation of the epidermis. These glands are numerously distributed: but especially so in the palms of the hand, and soles of the foot. In the former situation they amount, according to Professor Krause,[3] to 2736 in every square inch; and in the latter, to 2685. Mr. E. Wilson[4] counted the perspiratory pores on the palm of the hand, and found 3528 in a square inch; and each of these pores being the aperture of a little tube of about a quarter of an inch long, it follows, that in a square inch of skin, on the palm of the hand, there exists a length of tube equal to 882 inches, or 73½ feet. To obtain an estimate of the length of tube of the perspiratory system of the whole surface of the body, he thinks that 2800 might be taken as a fair average of the number of pores

[1] Art. Haut, in Wagner's Handwörterbuch der Physiologie, 7te Lieferung, s. 108.
[2] Op. cit., s. 131.
[3] Breschet, Nouvelles Recherches sur la Structure de la Peau, Paris, 1835.
[4] A Practical Treatise on Healthy Skin, p. 42, Lond., 1845.

in the square inch; and 700, consequently, of the number of inches in length. "Now the number of square inches of surface in a man of ordinary height and bulk is 2500; the number of pores, therefore, 7,000,000, and the number of inches of perspiratory tube, 1,750,000; that is, 145,833 feet or 48,600 yards, or nearly 28 miles!"

The marginal figure (Fig. 329) exhibits the transpiratory apparatus magnified.

Numerous experiments have been instituted for the purpose of discovering the quantity of transpiration in a given time. Of these, the earliest were by Sanctorius,—for which he is more celebrated than for any of his other labours,—after whom the cutaneous transpiration was called *Perspirabile Sanctorianum*.[1] For thirty years, this indefatigable experimentalist weighed daily, with the greatest care, his solid and liquid ingesta and egesta, and his body, with the view of deducing the loss sustained by the cutaneous and pulmonary exhalations. He found, that every twenty-four hours his body returned to the same weight, and that he lost the whole of the ingesta;—five-eighths by transpiration, and three-eighths by the ordinary excretions. For eight pounds of ingesta, there were only three pounds of sensible egesta, which consisted of forty-four ounces of urine, and four of fæces. It is lamentable to reflect, that so much time was occupied in the attainment of such insignificant results. The self-devotion of Sanctorius gave occasion, however, to the institution of numerous experiments of the same kind; as well as to discover the variations in the exhalation, according to age, climate, &c. The results of these have been collected by Haller,[2] but they afford little instruction; especially as they were directed to the transpiration in general, without affording any data from which to calculate the proportion exhaled from the lungs compared with that constantly given off by the cutaneous surface. Rye,[3] who dwelt in Cork, lat. 51° 54′, found, in the three winter months—December, January, and February—that the quantity of urine was 3937 ounces; of perspiration, 4797;—in the spring months—March, April, and May—the urine amounted to 3558; the perspiration to 5405; in the summer months—June, July, and August—the former amounted to 3352; the latter to 5719; and in the three autumnal months—September, October, and November—the quantity of urine was 3369; of perspiration 4471. The daily average estimate in ounces was as follows:—

	Urine.	Perspiration.
Winter, - - - - - -	$42\frac{7}{10}$	53
Spring, - - - - - -	40	60
Summer, - - - - - -	37	63
Autumn, - - - - - -	37	50

thus making the average daily excretion of urine, throughout the year, to be a little more than 39 ounces; and of the transpiration, 56 ounces. Keill,[4] on the other hand, makes the average daily perspiration, 31

1 Ars Sanctorii de Staticâ Medicinâ, cum Comment. Martini Lister, Lugd. Bat., 1711.
2 Elem. Physiol., xii. 2, 10.
3 Rogers on Epidem. Diseases, Appendix, Dubl., 1734.
4 Tentamina Medico-Phys.—Appendix, Lond., 1718.

ounces; that of the urine 38; the weight of the fæces being 5 ounces, and of the solid and liquid ingesta, 75. His experiments were made at Northampton, England, lat. 52° 11′. Bryan Robinson[1] found, as the result of his observations in Ireland, that the ratio of the perspiration to urine was, in summer, 5 to 3; in winter, 2 to 3; whilst in April, May, October, November and December, they were nearly equal. In youth, the ratio of the perspiration to urine was 1340 to 1000; in the aged, 967 to 1000. Hartmann, when the solid and liquid ingesta amounted to 80 ounces, found the urine discharged 28 ounces; the fæces, 6 or 7 ounces; and the perspirable matter, 45 or 46 ounces. De Gorter,[2] in Holland, when the ingesta were 91 ounces, found the perspiration amount to 49 ounces; the urine to 36; and the fæces to 8. Dodart[3] asserts, that in France, the ratio of the perspiration to the fæces is as 7 to 1; and to the whole egesta 15 to 12 or 10. The average perspiration in the twenty-four hours, he estimates at 33 ounces and two drachms; and Sauvages, in the south of France, found, that when the ingesta were 60 ounces in the day, the transpiration amounted to 33 ounces; the urine to 22; and the fæces to 5. But most of these estimates were obtained in the cooler climates,—the "*regiones boreales*,"—as Haller[4] has, not very happily, termed them.

According to Lining,[5] whose experiments were made in South Carolina, lat. 32° 47′, the perspiration exceeded the urine in the warm months; but in the cold, the latter had the preponderance. The following table, quoted by Haller, gives the average daily proportion of urine and perspiration, for each month of the year, in ounces.

	Urine.	Perspiration.
December,	70·81	42·55
January,	72·43	39·97
February,	77·86	37·45
March,	70·59	43·23
April,	59·17	47·72
May,	56·15	58·11
June,	52·90	71·39
July,	43·77	86·41
August,	55·41	70·91
September,	40·60	77·09
October,	47·67	40·78
November,	63·16	40·97

After the period at which Haller wrote, no experiments of any moment were adopted for appreciating the transpiration. Whenever trials were instituted, the exhalation from both the skin and lungs was included in the result, and no satisfactory means were adopted for separating them, until MM. Lavoisier and Séguin[6] made their celebrated experiments. M. Séguin enclosed himself in a bag of gummed taffeta, which was tied above the head, and had an aperture the edges of which were fixed around the mouth by a mixture of turpentine and pitch. By means of this arrangement, the pulmonary transpiration

[1] Dissertation on the Food and Discharges of Human Bodies, Dublin, 1748.
[2] De Perspiratione Insensibili, Lugd. Bat., 1736.
[3] Mémoir. de l'Acad. des Sciences, ii. 276.
[4] Op. cit.
[5] Philos. Transact. for 1743 and 1745.
[6] Mémoir. de l'Académ. des Sciences de Paris, Paris, 1777 and 1790.

alone escaped into the air. To estimate its quantity, it was merely necessary for M. Séguin to weigh himself in the sac by a very delicate balance, at the commencement and termination of the experiment. By repeating it out of the sac, he determined the total quantity of transpired fluid; so that by deducting from this the quantity of fluid exhaled from the lungs, he obtained the amount of cutaneous transpiration. He, moreover, kept an account of the food which he took; of the solid and liquid egesta; and, as far as he was able, of every circumstance that could influence the transpiration.

The results—as applicable to Paris, at which MM. Lavoisier and Séguin arrived, by a series of well-devised and well-conducted experiments—were the following:—*First.* Whatever may be the quantity of food taken, or the variations in the state of the atmosphere, the same individual, after having increased in weight by the whole quantity of nourishment taken, returns daily, after the lapse of twenty-four hours, to nearly the same weight as the day before;—provided he is in good health: his digestion perfect; not fattening nor growing; and avoids all kind of excess. *Secondly.* If, when all other circumstances are identical, the amount of food varies; or if—the amount of food being the same—the effects of transpiration differ, the quantity of the excrements augments or diminishes, so that every day at the same hour, we return nearly to the same weight; proving, that when digestion goes on well, the causes, that concur in the loss or excretion of the food taken in, afford each other mutual assistance,—in the state of health one charging itself with what the other is unable to accomplish. *Thirdly.* Defective digestion is one of the most direct causes of diminution of transpiration. *Fourthly.* When digestion goes on well, and the other causes are equal, the quantity of food has but little effect on the transpiration. M. Séguin affirms, that he has very frequently taken at dinner two pounds and a half of solid and liquid food; and at other times four pounds; yet the results in the two cases differed but little,—provided only, the quantity of fluid did not vary materially in the two cases. *Fifthly.* Immediately after dinner, the transpiration is at its minimum. *Sixthly.* When all other circumstances are equal, the loss of weight induced by insensible transpiration is at its maximum during digestion. The increase of transpiration during digestion compared with the loss sustained when fasting, is, on an average, $2\frac{3}{10}$ grains per minute. *Seventhly.* When circumstances are most favourable, the greatest loss of weight caused by insensible transpiration was, according to their observations, 32 grains per minute; consequently 3 ounces, 2 drachms and 48 grains *poids de marc*, per hour; and 5 pounds in twenty-four hours, under the calculation, that the loss is alike at all hours of the day, which is not, however, the fact. *Eighthly.* When all the accessory circumstances are least favourable, provided only that digestion is properly accomplished, the smallest loss of weight is 11 grains per minute; consequently, 1 ounce, 1 drachm and 12 grains per hour; and 1 pound, 11 ounces and 4 drachms in the twenty-four hours. *Ninthly.* Immediately after eating, the loss of weight caused by the insensible perspiration is $10\frac{1}{2}$ grains per minute during the time at which all the extraneous causes are most unfavour-

able to transpiration; and $19\frac{1}{10}$ grains per minute when these causes are most favourable, and the internal causes are alike. "These differences," says M. Séguin, "in the transpiration after a meal, according as the causes influencing it are more or less favourable, are not in the same ratio with the differences observed at any other time when the other circumstances are equal; but we know not how to account for the phenomenon." *Tenthly.* The cutaneous transpiration is immediately dependent both on the solvent virtue of the circumambient air, and the power possessed by the exhalants of conveying the perspirable fluid as far as the surface of the skin. *Eleventhly.* From the average of all the experiments it seems, that the loss of weight caused by the insensible transpiration is 18 grains per minute; and that, of these 18 grains, 11, on the average, belong to the cutaneous transpiration, 7 to the pulmonary. *Twelfthly.* The pulmonary transpiration, compared with the volume of the lungs, is much more considerable than the cutaneous, compared with that of the surface of the skin. *Thirteenthly.* When all other circumstances are equal, the pulmonary transpiration is nearly the same before and immediately after a meal; and if, on an average, it is $17\frac{1}{5}$ grains per minute before dinner, it is $17\frac{7}{10}$ grains after dinner. *Lastly.* All intrinsic circumstances being equal, the weight of the solid excrements is least during winter.

Although these results are probably fairly deduced from the experiments; and the experiments themselves almost as well conceived as the subject admits of, we cannot regard the estimates as more than approximations. Independently of the fact, that the envelope of taffeta must necessarily have retarded the exhalation, by shutting off the air, and causing more to pass off by pulmonary transpiration, the perspiration must incessantly vary, according to circumstances within and without the system: some individuals, too, perspire more readily than others; and the amount exhaled is dependent, as we have seen, upon climate and season,—and likewise upon the quantity of fluid received into the digestive organs. From all these and other causes, Bichat is led to observe, that the endeavour to determine the quantity of the cutaneous transpiration is as vain as to endeavour to specify what quantity of water is evaporated every hour on a fire, the intensity of which is varying every instant. To attempt, however, the solution of the problem, experiments were undertaken by Cruikshank,[1] and by Abernethy. Their plan consisted in confining the hand, for an hour, in an air-tight glass jar, and collecting the transpired moisture. Mr. Abernethy, having weighed the fluid collected in the glass, multiplied its quantity by $38\frac{1}{2}$, the number of times he conceived the surface of the hand and wrist to be contained in the whole cutaneous surface. This gave $2\frac{1}{2}$ pounds, as the amount exhaled from the skin in the twenty-four hours, on the supposition, that the whole surface perspires to an equal extent. These experiments have been repeated by Dr. William Wood,[2] of Newport, England, with some modifications. He pasted around the mouth of a jar one extremity of a bladder the ends of which were cut away, and

[1] Experiments on the Insensible Perspiration, p. 5, Lond., 1795.
[2] An Essay on the Structure and Functions of the Skin, &c., Edinb., 1832.

the hand being passed through the bladder into the jar, the other extremity was bound to the wrist with a ligature, not so tight, however, as to interfere, in any degree, with the circulation. The exact weight of the jar and bladder had previously been ascertained. During the experiment, cold water was applied to the outer surface of the jar, to cause the deposition of the fluid accumulated within. The result of his experiments was as follows:—

Exp.	Time of day.	Temperature in apartment.	Pulse per minute.	Fluid collected in an hour.
1	Noon. - -	66° - -	84 - -	32 grs.
2	Do. - -	66 - -	78 - -	32
3	Do. - -	66 - -	78 - -	26
4	Do. - -	61 - -	84 - -	32
5	9 P.M. - -	62 - -	80 - -	26
6	Do. - -	62 - -	75 - -	23
	Mean	63·8	79·8	28·5

The next thing was to estimate the proportion, which the surface of the hand and wrist bears to the whole surface of the body. Mr. Abernethy reckoned it as 1 to 38½, and Mr. Cruikshank as 1 to 60! Dr. Wood does not adopt the estimate of either. He thinks, however, that the estimate of the former as regards the surface of the hand and wrist, which he makes seventy square inches, is near the truth, having found it correspond both with his own measurements and the reports of glovers. Mr. Abernethy's estimate of the superficial area of the whole body—2700 square inches, or above eighteen square feet, he regards as too high. Perhaps the most general opinion is, that it amounts to sixteen square feet, or 2304 square inches; but Haller did not think it exceeded thirteen square feet, or 2160 square inches. Dr. Wood adopts the former of these estimates, and is disposed to think, that the proportion of the surface of the hand and fingers, taken to the extremity of the bone of the arm, does not fall short of 1 to 2, which if we adopt the ratio of the quantity, he found transpired per hour, gives, for the whole body, about forty-five ounces, or nearly four pounds troy in the twenty-four hours. This is considerably above the result of the experiments of either Séguin or Abernethy; yet, on reviewing the experiments, Dr. Wood is not disposed to think it far from the truth.

Upwards of fifty years ago, Dr. Dalton, of Manchester, undertook a series of experiments similar to those of Sanctorius, Keill, Hartmann and Dodart.[1] The first he made upon himself in the month of March, for fourteen days in succession. The aggregate of the articles of food consumed in this time was as follows,—bread, 163 ounces avoirdupois; oaten cake, 79 ounces; oatmeal, 12 ounces; butcher's meat 54½ ounces; potatoes, 130 ounces; pastry, 55 ounces; cheese, 32 ounces;—Total of solid food, 525½ ounces; averaging 38 ounces daily;—of milk, 435½ ounces; beer, 230 ounces; tea, 76 ounces;—Total of liquid food, 741½, averaging 53 ounces of fluid daily. The daily consumption was, consequently, 91 ounces; or nearly six pounds. During the same period, the total quantity of urine passed was 680 ounces; of fæces, 68 ounces—the daily average being,—of urine, 48½ ounces; of fæces, 5 ounces:

[1] Manchester Memoirs, vol. v.

making $53\frac{1}{2}$ ounces. If we subtract these egesta from the ingesta, there will remain $37\frac{1}{2}$ ounces, which must have been exhaled by the cutaneous and pulmonary transpirations, on the supposition that the weight of the body remained stationary. To test the influence of difference of seasons, Dr. Dalton resumed his investigations in the month of June of the same year. The results were as might have been anticipated,—a less consumption of solids and a greater of fluids; a diminution in the evacuations and an increase in the insensible perspiration. The average of solids consumed per day was 34 ounces; of fluids, 56 ounces;—total, 90 ounces; the daily average of the evacuations—urine, 42 ounces; fæces, $4\frac{1}{3}$,—leaving a balance of nearly 44 ounces for the daily loss by perspiration, or one-sixth more than during the cooler season. He next varied the process, with the view of obtaining the quantity of perspiration, and the circumstances attendant upon it more directly. He procured a weighing beam, that would turn with one ounce. Dividing the day into periods of four hours in the forenoon, four or five in the afternoon, and nine in the night—or from ten o'clock at night to seven in the morning—he endeavoured to find the perspiration corresponding to these periods respectively. He weighed himself directly after breakfast, and again before dinner, observing neither to take, nor part, with, any thing in the interval, except what was lost by perspiration. The difference in weight indicated such loss. The same course was followed in the afternoon and night. This train of experiments was continued for three weeks in November. The mean hourly losses by transpiration were;—in the morning, 1·8 ounce avoirdupois;—afternoon, 1·67 ounce; night, 1·5. During twelve days of this period he kept an account of urine corresponding in time with perspiration. The ratio was as 46 to 33. From the whole of his investigations on this subject, Dr. Dalton concludes;—that of six pounds of aliment taken in the day, there appears to be nearly one pound of carbon and nitrogen together; the remaining five pounds are chiefly water, which seems necessary as a vehicle to introduce the other two elements into the circulation, and also to supply the lungs and membranes with moisture;—that very nearly the whole quantity of food enters the circulation, for the fæces constitute only $\frac{1}{18}$th part, and of these a part—bile—must have been secreted;—that one great portion is thrown off by the kidneys, namely, about half of the whole weight taken, but probably more or less according to climate, season, &c.;—that another great portion is thrown off by means of insensible perspiration, which may be subdivided into two parts, one of which passes off by the skin—amounting to one-sixth part, and the other five-sixths are discharged from the lungs in the form of carbonic acid, and water or aqueous vapor.

Since the time of Lavoisier and Séguin, M. Edwards[1] instituted experiments with the view of illustrating the effect produced upon cutaneous transpiration by various circumstances to which the body is subjected. His first trials were made on cold-blooded animals, in which the cutaneous transpiration can be readily separated from the pulmonary, owing

[1] Sur l'Influence des Agens Physiques, Paris, 1822; or Hodgkin's and Fisher's translation Lond., 1832.

to the length of time they are capable of living without respiring. All that was necessary was to weigh the animal before and after the experiment, and to make allowance for the ingesta and egesta. In this way he discovered, that the body loses successively less and less in equal portions of time;—that the transpiration proceeds more rapidly in dry than in moist air; in the extreme states nearly in the proportion of 10 to 1;—that temperature has, also, considerable influence,—the transpiration at 68° of Fahrenheit, being twice as much; and at 104°, seven times as much as at 32°. He likewise found, that frogs transpire, whilst they are in water, as is shown by the diminution they experience while immersed in that fluid, and by the appearance of the water itself, which becomes perceptibly impregnated with the matter excreted by the skin. In warm-blooded animals, as in the cold-blooded, the transpiration became less and less in proportion to the quantity of fluid evaporated from the body; and he observed the same difference between the effects of moist and dry air, and between a high and a low temperature. The effects of these agents were essentially the same on man as on animals. He found, that the transpiration was more copious during the early than the latter part of the day; and after taking food; and, on the whole, it appeared to be increased during sleep.

Whenever the fluid, which constitutes the insensible transpiration, does not evaporate, owing to causes referred to at the commencement of this article, it appears on the surface in the form of *sensible perspiration* or *sweat.* It has been supposed by some physiologists, that the insensible and sensible perspirations are two distinct functions. Such appears to be the opinion of Haller, and of M. Edwards, who regards the former as a physical *evaporation*,—the latter as a vital *transudation* or secretion; but no sufficient reason seems to exist, why we should not regard them as different degrees of the same function. Very recently, indeed, it has been maintained by Mr. Rainey,[1] as the results of careful histological inquiry, that there are no glands but the sudoriparous on the integument of the hands and feet, and hence it is inferred by him, that these glands furnish the oily or sebaceous matter with which these parts are anointed; and in place of regarding the sweat as an increase of the insensible perspiration, he esteems it an increased secretion of glands, which, in their less active state, secrete sebaceous matter, and, in their more active, the fluid of transpiration.

It has been affirmed, that the sweat is generally less charged with carbonic acid than the vapour of transpiration; and that it is richer in salts, which are deposited on the skin, and are sometimes seen in the form of white flocculi; but our knowledge on this matter is vague. There can be no doubt, however, that a large portion of the transpiration —pulmonary and cutaneous—consists of the fluid of evaporation,—the smaller portion, which is the true matter of perspiration, being the secretion of sudoriferous glands. To establish the amount of the fluids of evaporation and secretion, Krause[2] endeavoured both to number and measure these glands. On an average, he says, in each superficial square inch of

[1] Proceedings of the Royal Medical and Chirurgical Society, June 22, 1849, and London Med. Gaz., July 20, 1849.

[2] Art. Haut, in Wagner's Handwörterbuch der Physiologie, 7te Lieferung, s. 108, Braunschweig, 1844.

the body there are 1000 orifices and glands of $\frac{1}{6}$th of a line in diameter; the greatest and least numbers in this space being, in the palm, 2736; in the sole, 2685; in the cheek, 548; in the neck, back, and nates, 417. The whole number, excluding the axilla, in which they are peculiarly large and thickset, is estimated at about 2,381,248. Adopting these numbers, and supposing each gland to be occupied by a column of fluid presenting at the orifice a hemispherical surface $\frac{1}{56}$th of a line in diameter—the size, which Krause found by admeasurement of some drops in a warm and moist, but not sweating skin—the whole of the glands would present an evaporating surface of 7896 square inches. Krause, therefore, considers it probable—according to ascertained laws of evaporation, and experiments instituted for the purpose—that only a portion of the fluid discharged by cutaneous transpiration is furnished by these glands; inasmuch as there could not be more than 3365 grains evaporated in the twenty-four hours from such a surface under favourable circumstances, whereas the experiments of MM. Lavoisier and Séguin—as has been shown—gave an average of 11 grains per minute, or 15,840 grains in the twenty-four hours,—leaving 12,475 grains to be accounted for probably by evaporation. But these are, of course, mere approximations to the truth.

Careful examinations have been made by Valentin[1] on his own person, in regard to the amount of both cutaneous and pulmonary transpiration. Taking three days of ordinary life in September, weighing himself naked fifteen times a day, and all his ingesta and sensible excretions, he found the averages of three days to be:—nutritive matter taken, 45325·5 grains; excrement, 2956·3 grains; urine, 22439·3 grains; perspiration, 19327·4 grains. The ingesta being as 1, the excrement was ·065, the urine, ·503; and the perspiration, ·422. There were differences, however, in the days;—in the first, the proportion of the ingesta to the excretions was as 1·097 to 1; in the second, as 1·028 to 1; in the third, as 1 to 1·090. The hourly amount of transpiration was occasionally $4\frac{1}{2}$ times as much as at others; the greatest difference being caused by whatever excited sweating, or perceptible moisture of the skin. For instance, on the same day, the hourly amount, after taking two cups of coffee, and during gentle perspiration, was 1213·65 grains; in the forenoon, in pretty active exercise and sweating, 1402·75 grains; and in the evening, during copious sweating from exercise, 2056·85 grains; but whilst writing quietly in the forenoon of the same day it fell to 858·7 grains, and three or four hours after dinner, it was only 509·95 grains. Nothing influenced the transpiration so much as rest and bodily exertion. Even when the latter did not produce manifest sweating, the effect was considerable. After eating, also, transpiration was generally increased, and its minimum was observed during fasting, and whilst at rest in a cool temperature. During the night and in sleep, the transpiration was diminished; but not more than in rest during the day. Mental exertion had no obvious influence.

Particular parts of the body perspire more freely, and sweat more

[1] Lehrbuch der Physiologie des Menschen, B. i. s. 582; and Krause, op. cit., s. 140.

readily than others. The forehead, armpits, groins, hands, feet, &c., exhibit evidences of this most frequently; some of them perhaps, owing to the fluid, when exhaled, not evaporating readily,—the contact of air being impeded. It is presumed, likewise, that the sweat has not every where the same composition. Its odour certainly varies in different parts. In the armpits and feet it is generally considered to be more acid; but M. Donné[1] affirms, that there, as well as around the genital organs and between the toes, and wherever it is most odorous, it is alkaline, restoring the blue of litmus paper which had been previously reddened by an acid. He properly suggests, however, that this may be owing to admixture with the secretion of the follicles. In the violent sweats that accompany acute rheumatism, its acidity always attracts attention; and in the groins, its odour is strong and rank. It differs greatly, too, in individuals, and especially in races. In the red-haired, it is said to be unusually strong; and in the negro, during the heat of summer, alliaceous and overwhelming. By cleanliness, the red-haired can obviate the unpleasant effect in a great measure by preventing undue accumulation in the axilla, groins, &c.; but no ablution can remove the odour of the negro, although cleanliness detracts from its intensity. Each race appears to have its characteristic odour; and, according to Humboldt, the Peruvian Indian, whose smell is highly developed by education, can distinguish the European, American Indian, and negro, in the middle of the night, by this sense alone. Certain anatomists and physiologists—as has been seen (p. 282)—have doubted, whether this special odorous matter of the skin belongs properly to the perspiration, and have presumed it to be the product of special organs. This is, however, by no means established; and the experiments of M. Thénard, as well as the facts just mentioned, would rather seem to show, that the matter of sweat itself has, within it, the peculiar odour. Simon,[2] too, affirms, that on evaporating his own sweat, the peculiar smell of the axilla was observed, and an odour of ammonia was developed: and allusion has been made to the recent view of Mr. Rainey, that the same glands may in one condition of activity furnish the matter of transpiration, and in another the ordinary secretion of sebaceous follicles. The fact of the dog tracing its master to an immense distance, and discovering him in a crowd, has induced a belief, that the scent may be distinct from the sweat; but the supposition is not necessary, if we admit the matter of perspiration to be itself odorous. There can be no doubt, however, that certain odorous secretions are formed by cutaneous follicles.

The singular fact has been stated, that by mixing fresh blood with one-third or one-half its bulk of strong sulphuric acid, and stirring the mixture with a glass rod, a peculiar odour is evolved, which differs in the blood of man and animals, and in the blood of the two sexes. This odour resembles that of the cutaneous perspiration of the animal. "They have hereby pretended to determine," says a recent medico-legal writer,[3] "whether any given specimen of blood had belonged to

[1] Cours de Microscopie, p. 207, Paris, 1844.
[2] Animal Chemistry, Sydenham Society edition, ii. 102, Lond., 1846.
[3] Taylor, Medical Jurisprudence, Amer. edit., by Dr. Griffith, p. 275, Philad., 1845.

a man, a woman, a horse, sheep, or fish. Others pretend, that they have been able to identify the blood of frogs and fleas!" The first person who directed attention to this point was M. Barruel;[1] who was of opinion that a knowledge of the fact might be important in a medico-legal relation, with the view of determining the source of spots of blood on linen for example; but even admitting the fact, as stated by MM. Barruel, Devergie,[2] and others, it is obvious, that so much must depend upon the power of olfactory discrimination of the observer, that the evidence in any doubtful case could scarcely be deserving of much weight. Mr. Taylor, indeed, affirms, that there is probably not one individual among a thousand, whose sense of smell could be so acute as to allow him to state, with undeniable certainty, from what animal the unknown blood had really been taken.

Besides the causes before referred to, the quantity of perspiration is greatly augmented by running or violent exertion of any kind; especially if the temperature of the air be elevated. Warm fluids favour it greatly; hence their use, alone or combined with sudorifics, when this class of medicines is indicated. M. Magendie[3] conceives, that being readily absorbed they are readily exhaled. This may be true; but the perspiration breaks out too rapidly to admit of this explanation. When ice-cold drinks are taken in hot weather, the cutaneous transpiration is instantaneously excited. The effect, consequently, must be produced by the refrigerant influence of the cold medium on the lining membrane of the stomach,—this influence, being propagated, by sympathy, to every part of the capillary system. The same explanation is applicable to warm drinks; but the hot exert a sympathetic effect on the skin by virtue of their stimulant action on the mucous membrane.

With regard to the uses of the insensible transpiration, it has been supposed to preserve the surface supple, and thus favour the exercise of touch; and also, by undergoing evaporation, to aid in the refrigeration of the body. It is probable, however, that these are secondary uses under ordinary circumstances; and that the great office performed by it is to remove a certain quantity of fluid from the blood: hence it has been properly termed the *cutaneous depuration*. In this respect, it bears a striking analogy to the urine, which is the only other depuratory secretion, with the exception of the pulmonary transpiration, which we shall find essentially resembles the cutaneous. Being depuratory, it has been conceived, that any interruption to transpiration must be followed by serious consequences; accordingly most diseases have, from time to time, been ascribed to this cause. There is, however, so great a compensation existing between the urinary and cutaneous depurations, that if one be augmented, the other is decreased,—and conversely. Besides, it is well known, that disease is more apt to be induced by partial and irregular application of cold than by frigorific influences of a more general character. The Russian vapour-bath exemplifies this; the bather frequently passing with impunity from a temperature of 130° into cold water. The morbific effect—in these cases

[1] Annales d'Hygiène, i. 267.
[2] Médecine Légale, 2de édit., iii. 761, Paris, 1840.
[3] Précis de Physiologie, 2de édit., ii. 455.

of fancied check given to perspiration—is derangement of the apparatus engaged in the important functions of nutrition, calorification, and secretion, and the extension of this derangement to every part of the organism.

As the *sensible transpiration* or *sweat* is probably only the insensible perspiration in increased quantity, with the addition of saline, and other matters that are not evaporable, its uses demand no special notice.

2. *The Lachrymal Secretion.*

The lachrymal apparatus, being a part of that accessory to vision, was described under another head (vol. i. p. 283).

The tears, as we meet with them, are not simply the secretion of the lachrymal gland, but of the conjunctiva, and occasionally of the caruncula lachrymalis and follicles of Meibomius. It has been presumed, too, by several modern ophthalmologists—by Wardrop, Rosas, Jüngken, for example—that a portion of them—Rognetta[1] says the principal portion—consists of the aqueous humour, which passes through the cornea by endosmose; but although such endosmose *may* exist, it can assuredly furnish but little towards the composition of the tears.[2] They have a saline taste; mix freely with water; and, owing to the presence of free soda, communicate a green tint to blue infusion of violets. Their chief salts are chloride of sodium, and phosphate of soda. According to M. Fourcroy and Vauquelin,[3] the animal matter of the tears is mucus; but it is presumed, by some, to be albumen or an analogous principle—*dacryolin*. They found them to consist of water, mucus, chloride of sodium, soda, phosphate of lime and phosphate of soda. The following is the result of analyses by Professor Frerichs:[4]—

	I.	II.
Water,	99·06	98·70
Solid constituents,	0·94	1·30
Epithelium,	0·14	0·32
Albumen,	0·08	0·10
Chloride of Sodium—Alkaline Phosphates, Earthy Phosphates, Mucus, Fat,	0·72	0·88

When tears are examined with the microscope, globules of mucus, and *debris* of the epidermis are seen in them.

This secretion is more influenced by the emotions than any other; and hence it is concerned in the expressions of lively joy or sorrow, especially the latter.

3. *The Salivary Secretion.*

The salivary apparatus has likewise engaged attention elsewhere. It consists of a *parotid* gland on each side, situate in front of the ear, and

[1] Traité Philosophique et Clinique d'Ophthalmologie, p. 705, Paris, 1844.

[2] Frerichs, Art. Thränensecretion in Wagner's Handwörterbuch der Physiologie, 19te Lieferung, s. 621, Braunschweig, 1848.

[3] Journal de Physique, xxxix. 256.

[4] Op. cit., s. 618.

behind the neck and ramus of the jaw; a *submaxillary*, beneath the body of the bone; a *sublingual*, situate immediately beneath the tongue;—and an *intralingual* or *lingual*, seated at the inferior surface of the tongue;—the parotids and submaxillary glands having each but one excretory duct,—the sublingual several.[1] The structure of the salivary glands in man greatly resembles that of the mammary glands. The marginal figure exhibits their structure in the sheep. All these glands pour their respective fluids into the mouth, where it collects, and becomes mixed with the exhalation of the mucous membrane of the mouth, and the secretion from its follicles. It is this mixed fluid that has generally been analyzed by the chemist. When collected without the action of sucking, it is of a specific gravity varying from 1·004 to 1·009; translucent; slightly opaque; very frothy; and ultimately deposits a nebulous sediment. Even with the purest saliva there are always found mixed a few epithelial cells, derived from the mucous lining of the mouth, or from the excretory ducts of the secreting glands. It usually contains free alkali: in rare cases, during meals, Professor Schultz,[2] of Berlin, found it acid; and during fasting, it is occasionally neutral. Mitscherlich,[3] indeed, affirms, that it is acid whilst fasting; but becomes alkaline during eating,—the alkaline character disappearing, at times, with the first mouthful of food. The average amount of the secretion in the twenty-four hours does not probably exceed four ounces. According to Berzelius,[4] its constituents are—water, 992·2; peculiar animal matter, 2·9; mucus, 1·4; chlorides of potassium and sodium, 1·7; lactate of soda, and animal matter, 0·9; soda, 0·2. Drs. Bostock[5] and Thomas Thomson[6] think that the "mucus" of Berzelius resembles coagulated albumen in its properties. In the tartar of the teeth, which seems to be a sediment from the saliva, Berzelius found 79 parts of earthy phosphate; 12·5 of undecomposed mucus; 1 part of a matter peculiar to the saliva, and 7·8 of an animal matter soluble in chlorohydric acid. This animal matter, according to the microscopic experiments of M. Raspail,[7] is composed of deciduous fragments from the mucous membrane of the cavity of

Fig. 330.

Lobules of the Parotid Gland, in the Embryo of the Sheep, in a more advanced condition. (Müller.)

[1] Vol. i. p. 516.
[2] Hecker, Wissenschaftliche Annalen, B. ii. H. i. § 32, 1835.
[3] Rullier and Raige-Delorme, art. Digestion, Dict. de Médecine, 2de édit., x. 300, Paris, 1835.
[4] Medico-Chirurgical Transactions, iii. 242.
[5] Physiol., ed. cit., p. 487.
[6] System of Chemistry, vol. iv.
[7] Nouveau Système de Chimie Organique, p. 454.

the mouth; and he considers, that the saliva is nothing more than an albuminous solution, mixed with different salts, that are capable of modifying more or less its solubility in water, and of shreds or layers of tissue. MM. Leuret and Lassaigne[1] analyzed *pure* saliva, obtained from an individual labouring under salivary fistula, and found it to contain,—water, mucus, traces of albumen, soda, chloride of potassium, chloride of sodium, carbonate and phosphate of lime:—and Messrs. Tiedemann and Gmelin[2] affirm,—and their analysis agrees pretty closely with that of Van Setten[3]—that it has only one or two hundredths of solid matter, which are composed of a peculiar substance, called *salivary matter* or *ptyalin*, osmazome, mucus, perhaps albumen, a little fat containing phosphorus, and the insoluble salts—phosphate and carbonate of lime. Besides these, they detected the following soluble salts;—acetate, carbonate, phosphate, sulphate, sulphocyanate of potassa; and chloride of potassium. Treviranus[4] thinks the saliva contains a peculiar acid, to which he gives the name Blausäure, probably combined with an alkali; but its chemical properties resemble the sulpho-cyanic acid so greatly, that according to Kastner[5] they may be taken for each other. As the result of numerous analyses, Dr. Wright[6] gives the following constituents of healthy saliva;—water, 988·1; ptyalin, 1·8; fatty acid, ·05; chlorides of sodium and potassium, 1·4; albumen with soda, 0·9; phosphate of lime, 0·6; albuminate of soda, ·08; lactates of potassa and soda, ·07; sulphocyanide of potassium, ·09; soda, ·05; mucus with ptyalin, 2·6.

Fig. 331.

Distribution of Capillaries around the follicles of Parotid Gland.

Saliva has also been carefully analyzed by Enderlin,[7] who concludes that, like the blood, it contains no lactate, carbonate, or acetate; but its alkaline reaction is owing to the tribasic phosphate of soda, which serves also as a solvent of the mucus and protein compounds. The analysis of the ashes obtained from a very large quantity afforded, in 100 parts:—

Tribasic phosphate of soda,	28·122
Chlorides of sodium and potassium,	61·93
Sulphate of soda,	2·315
Phosphate of lime, " magnesia, " iron,	5·509

Still more recently, human saliva has been analyzed by Jacubowitsch[8] and found to be composed as follows:—

[1] Recherches, &c., sur la Digestion, p. 33, Paris, 1826.
[2] Recherches, &c., sur la Digestion, par Jourdan, Paris, 1827.
[3] De Salivâ ejusque Vi et Utilitate, Groning., 1837; cited in Brit. and For. Med. Rev., Jan., 1839, p. 236.
[4] Biologie, Band. iv. § 330.
[5] Ficinus, art. Speichel, in Pierer's Anat. Physiol. Real Wörterbuch, vii. 634, Altenb., 1827.
[6] London Lancet, Mar., 1842. [7] Annalen der Chemie und Pharmacie, Marz, 1844.
[8] De Salivâ, Dissert. inaugur. Med. Univers. Dorpatens; cited by Scherer, in Canstatt und Eisenmann's Jahresbericht über die Forstchritte der Biologie im Jahre 1848, Erlang., 1849.

Water,	999·16
Fixed residue,	4·84
Epithelium,	1·62
Organic matters,	1·34
Sulphocyanide of potassium,	0·06
Salts,	1·82

The salts consisted of phosphate of soda, 0·94; lime, 0·03; magnesia, 0·01; chlorides of potassium and sodium, 0·84.

Messrs. Tiedemann and Gmelin, and M. Donné,[1] found the saliva invariably alkaline, when the functions of the stomach were well executed. The last gentleman considered acidity of the stomach a diagnostic symptom of gastritis; and Dr. Robt. Thomson[2] observed the acid reaction in all cases of inflammation of the mucous and serous membranes. With the view of testing these points, Mr. Laycock[3] instituted numerous experiments, and tabulated the results of no less than 567 observations. His deductions do not accord with those of M. Donné. They are as follows:—1. The saliva may be acid without apparent disease of the stomach, and when the person is in good health. 2. It is alkaline during different degrees of gastric derangement, as indicated by the tongue. 3. It may be alkaline, acid and neutral, when the gastric phenomena are the same; and, consequently, acidity of the saliva is not a diagnostic mark of gastric derangement; and, lastly—in general it is alkaline in the morning, and acid in the evening. In a more recent work M. Donné[4] accounts for the varying testimony of different observers in regard to the chemical reaction of the saliva, by the greater or less proportion of the mucus of the mouth contained in the specimens subjected to examination. In the normal state, he affirms, it is alkaline; but the mucus secreted by the mucous membrane of the mouth being acid, the mixed fluid, to which the name saliva is given, must necessarily vary according to the proportion of each.

When saliva is examined by the microscope, it presents, besides a considerable number of lamellæ of epithelium, globules in variable quantity, which, according to M. Mandl,[5] proceed partly from the muciparous glands of the mouth, and partly from the salivary glands. They cannot, however, be distinguished from each other.

As the salivary secretion forms a part in the processes preparatory to stomachal digestion, its uses have been detailed in the first volume of this work, to which the reader is referred. The view of MM. Bernard and Barreswil, and of Mialhe, that the saliva contains an active principle, analogous in its physical and chemical characters to diastase, as well as its action on amylaceous substances, is there described.

A soft, whitish or yellowish matter, of greater or less thickness, is constantly deposited on the teeth, which, unless attention is paid, accumulates, and sometimes adheres to them with great force, constituting hard and dry concretions, known—as already remarked—under the

[1] Archives Générales, Mai & Juin, 1835; and Histoire Physiologique et Pathologique de la Salive, Paris, 1836. [2] Records of General Science, Dec., 1836.

[3] Lond. Med. Gazette, Oct. 7, 1837. See, for a detailed account of the saliva, Dr. S. Wright, op. cit.

[4] Cours de Microscopie, p. 208, Paris, 1844.

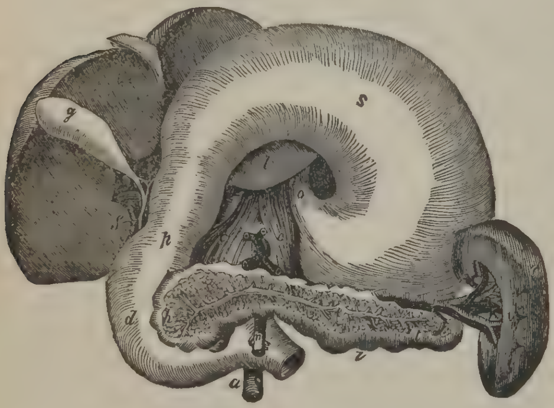
[5] Manuel d'Anatomie Générale, p. 488, Paris, 1843.

name of *tartar* or *tartar of the teeth.* Different views have existed in regard to its origin. Some have supposed it to be a secretion, others a deposition from the saliva, which is the most probable opinion; and others that it is an exhalation from the capillary vessels, to which the mucous membrane of diseased gums is liable. It has been affirmed by M. Mandl,[1] to be a collection of calcareous skeletons of infusoria, agglutinated by means of dried mucus.

4. *The Pancreatic Secretion.*

The *pancreas* or *sweetbread*, (Fig. 332, *h*, *t*, *i*,) secretes a juice or humour called *succus pancreaticus*, *pancreatic juice.* Its texture resembles that of the salivary glands; and hence it has been called by some the *abdominal salivary gland.* It is situate transversely in the abdomen; behind the stomach; towards the concavity of the duodenum; is about six inches in length, and between three and four ounces in weight. From the results of six examinations, Dr. Gross[2] gives the following as its mean weight and dimensions:—Weight $2\frac{1}{2}$ ounces; length, 7 inches; breadth at the body and splenic extremity, $16\frac{1}{2}$ lines; breadth at the neck, 12 lines; at the head, 2 inches and 3 lines; thickness at the body, neck, and splenic extremity, 4 lines; thickness at the head, 8 lines. M. Bécourt found the average length of thirty-two to be 8 inches; and the weight between three and four ounces.[3] It is of a reddish-white colour, and firm consistence. Its excretory ducts terminate in one,—called *duct of Wirsung*,—which opens into the duodenum, at times separately from the ductus communis choledochus, but close to it; at others, confounded with, or opening into, it.[4]

Fig. 332.



In this figure, which is altered from Tiedemann, the Liver and Stomach are turned up to show the Duodenum, the Pancreas, and the Spleen.

l. The under surface of the liver. *g*. Gall-bladder. *f*. The common bile-duct, formed by the union of a duct from the gall-bladder, called the cystic duct, and of the hepatic duct coming from the liver. *o*. The cardiac end of the stomach, where the œsophagus enters. *s*. Under surface of the stomach. *p*. Pyloric end of stomach. *d*. Duodenum. *h*. Head of pancreas; *t*, tail; and *i*, body of that gland. The substance of the pancreas is removed in front, to show the pancreatic duct (*e*) and its branches. *r*. The spleen. *v*. The hilus, at which the bloodvessels enter. *c*. Crura of diaphragm. *n*. Superior mesenteric artery. *a*. Aorta.

The amount of fluid secreted by the pancreas does not seem to be

[1] Gazette des Hôpitaux, 8 Août, 1843, p. 363.
[2] Elements of Pathological Anatomy, ii. 357, Boston, 1839.
[3] Recherches sur le Pancréas, ses Fonctions et ses Altérations Organiques, Thèse, Strasbourg, 1830, cited by Mondière, Archives Générales de Médecine, Mai, 1836.
[4] Magendie, Précis Elémentaire, i. 462; and J. P. Mondière, op. cit.

considerable. M. Magendie, in his experiments, was struck with the small quantity discharged. Frequently, scarcely a drop issued in half an hour; and, occasionally, a much longer time elapsed. Nor did he find that the flow, according to common opinion, and to probability, was more rapid whilst digestion was going on. It will be readily understood, therefore, that it cannot be an easy task to collect it. De Graaf[1] affirms, that he succeeded, by introducing into the intestinal end of the excretory duct, a small quill, terminating in a phial fixed under the belly of the animal. M. Magendie[2] states, that he tried this plan several times, but without success; and he believes it to be impracticable. The plan he adopts is to expose the intestinal orifice of the duct; to wipe the surrounding mucous membrane with a fine cloth, and as soon as a drop of the fluid oozes to suck it up by means of a *pipette* or small glass tube. In this way, he collected a few drops, but never sufficient to undertake a satisfactory analysis. Messrs. Tiedemann and Gmelin[3] make an incision into the abdomen; draw out the duodenum, and a part of the pancreas; and, opening the excretory duct, insert a tube into it; and a similar plan was adopted successfully on a horse by MM. Leuret and Lassaigne.[4] The difficulty experienced in collecting any quantity is a probable cause of some of the discrepancy amongst observers, regarding its sensible and chemical properties. Certain of the older physiologists affirm that it is acidulous and saline; others, that it is alkaline.[5] The majority of those of the present day compare it with saliva, and affirm it to be inodorous, insipid, viscid, limpid, and of a bluish-white colour. The latest experimenters by no means accord with each other. According to M. Magendie, it is of a slightly yellowish hue, saline taste, devoid of smell, occasionally alkaline, and partly coagulable by heat. MM. Leuret and Lassaigne found that of the horse—of which they obtained three ounces,—to be alkaline, and composed of 991 parts of water in 1000; an animal matter, soluble in alcohol; another, soluble in water; traces of albumen and mucus; free soda; chloride of sodium ; chloride of potassium, and phosphate of lime. In their view, consequently, the pancreatic juice strongly resembles saliva. Messrs. Tiedemann and Gmelin succeeded in obtaining upwards of two drachms of the juice in four hours; and, in 100 parts, found from five to eight of solid parts. These consisted of osmazome; a matter which became red by chlorine; another analogous to casein, and probably associated with salivary matter; much albumen; a little free acid, probably acetic; acetate, phosphate, and sulphate of soda, with a little potassa; chloride of potassium, and carbonate and phosphate of lime:—so that, according to these gentlemen, the pancreatic juice differs from saliva in containing—a little free acid, whilst saliva is alkaline; much albumen, and matter resembling casein; but little mucus and salivary matter, and no sulpho-cyanate of potassa. In an examination, by M. Blondlot,[6] of three or four grammes of fluid, obtained from the duct of a large dog, he found no evidences of albumen, when

[1] Tract. de Pancreat., Lugd. Bat., 1761; and Haller, Elem. Physiol., lib. xxii. sect. 8, Bern., 1764.

[2] Précis, &c., ii. 462. [3] Recherches, &c., i. 41. [4] Recherches, &c., p. 49.

[5] Haller, op. cit.; and Seiler, art. Pancreas, Pierer's Anat. Physiol. Real Wörterb., Band vi. 100, Altenb., 1825.

[6] Traité Analytique de la Digestion, p. 124, Paris, 1844.

he passed an electric current through it. He, also, holds it to be of the same nature as saliva.

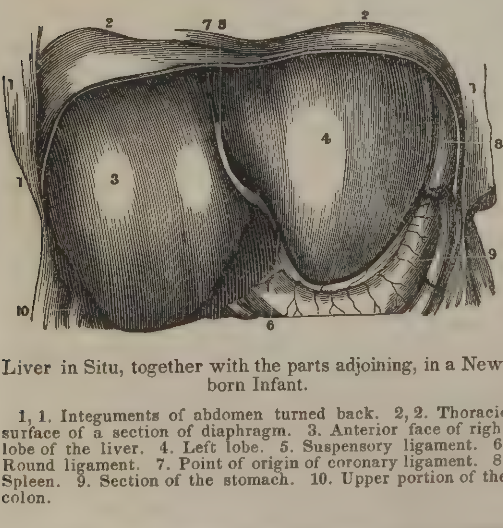
The precise use of the pancreatic juice in digestion—as we have previously seen—is not determined. Brunner[1] removed almost the whole pancreas from dogs, and tied and cut away portions of the duct; yet they lived apparently as well as ever. The secretion, therefore, cannot be indispensable. Its main uses seem to be to favour the absorption of oleaginous matters.[2]

5. *The Biliary Secretion.*

The biliary secretion is, also, a digestive fluid, and has been treated of in the appropriate place. The mode, however, in which the process is effected, has not yet been investigated. The apparatus consists of the *liver*, which accomplishes the formation of the fluid; the *hepatic duct*—the excretory channel, by which the bile is discharged; the *gall-bladder*, in which a portion of the bile is retained for a time; the *cystic duct*—the excretory channel of the gall-bladder; and the *ductus communis choledochus* or *choledoch duct*, formed by the union of the hepatic and cystic ducts, which conveys the bile immediately into the duodenum.

The *liver* (Fig. 333) is the largest gland in the body; situate in the abdomen beneath the diaphragm, above the stomach, the arch of the colon, and the duodenum; filling the whole of the right hypochondrium, and more or less of the epigastrium, and fixed in its situation by duplicatures of the peritoneum, called *ligaments of the liver*. The weight of the human organ is generally, in the adult, about three or four pounds. Some make the average about five pounds; but this is a large estimate. Of 60 male livers weighed, Dr. John Reid[3] found the average weight to be 52 oz. 12½ dr.: and of 25 female, 45 oz. 3½ dr. In disease, however, it sometimes weighs twenty or twenty-five pounds; and, at other times, not as many ounces. Its shape is irregular, and it is divided into three chief lobes, the *right*, *left*, and *lobulus Spigelii*. Its upper convex surface every where touches the arch of the diaphragm. The lower concave surface corresponds to the stomach, colon, and right

Fig. 333.



Liver in Situ, together with the parts adjoining, in a New-born Infant.

1, 1. Integuments of abdomen turned back. 2, 2. Thoracic surface of a section of diaphragm. 3. Anterior face of right lobe of the liver. 4. Left lobe. 5. Suspensory ligament. 6. Round ligament. 7. Point of origin of coronary ligament. 8. Spleen. 9. Section of the stomach. 10. Upper portion of the colon.

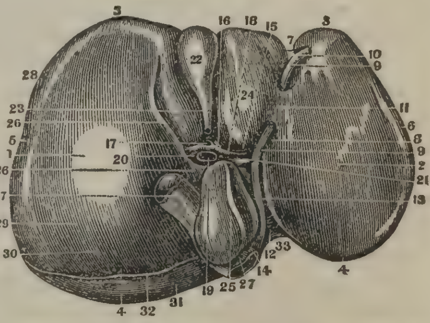
[1] Experimenta nova circa Pancreas, Amstel., 1683; and J. T. Mondière, op. cit.
[2] Vol. i. p. 614.
[3] Lond. and Edinb. Monthly Journ. of Med. Sciences, April, 1843, p. 323.

kidney. On the latter surface, two *fissures* are observable,—the one passing from before to behind, and lodging the umbilical vein in the fœtus—called *horizontal sulcus* or *fissure*, *great fissure* or *fossa umbilicalis;* the other cutting the last at right angles, and running from right to left, by which different nerves and vessels proceed to and from the liver, and called *principal fissure*, or *sulcus transversus.*

The liver itself is composed of the following anatomical elements: 1. The *hepatic artery*, a branch of the cœliac which ramifies minutely through the substance of the organ. The minuter branches of this vessel are arranged somewhat like the hairs in a painter's brush, and have hence been called *penicilli* of the liver. Mr. Kiernan[1] believes, that the blood, which enters the liver by the hepatic artery, fulfils three functions:—it nourishes the organ; supplies the excretory ducts with mucus; and, having fulfilled these objects, becomes venous; enters the branches of the portal veins, and not the radicles of the hepatic, as usually supposed, and contributes to the secretion of bile. 2. The *vena porta*, which, we have elsewhere seen, is the common trunk of the veins of the digestive organs and spleen. It divides like an artery, its branches accompanying those of the hepatic artery. Where it lies in the transverse fissure, it is of great size, and has hence been called *sinus venæ portæ.*

The possession of two vascular systems, containing blood, is peculiar, perhaps, to the liver, and has been the cause of difference of opinion, with regard to the precise fluid—arterial or venous—from which the bile is derived. According to Mr. Kiernan, the portal vein fulfils two functions: it carries the blood from the hepatic artery, and the mixed blood to the coats of the excretory ducts. It has been called *vena arteriosa*, because it ramifies like an artery, and conveys blood for secretion: but, as Mr. Kiernan has observed, it is an *arterial vein*, in another sense, as it is a vein to the hepatic artery, and an artery to the hepatic vein. 3. The *excretory ducts* or *biliary ducts.* These are presumed to arise from acini, communicating, according to some, with the extremities of

Fig. 334.



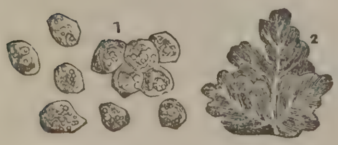
Inferior or Concave Surface of Liver, showing its Subdivisions into Lobes.

1. Centre of right lobe. 2. Centre of left lobe. 3. Its anterior, inferior or thin margin. 4. Its posterior, thick or diaphragmatic portion. 5. Right extremity. 6. Left extremity. 7. Notch on the anterior margin. 8. Umbilical or longitudinal fissure. 9. Round ligament or remains of umbilical vein. 10. Portion of the suspensory ligament in connexion with the round ligament. 11. Pons hepatis, or band of liver across the umbilical fissure. 12. Posterior end of longitudinal fissure. 13, 14. Attachment of obliterated ductus venosus to ascending vena cava. 15. Transverse fissure. 16. Section of hepatic duct. 17. Hepatic artery. 18. Its branches. 19. Vena portæ. 20. Its sinus, or division into right and left branches. 21. Fibrous remains of ductus venosus. 22. Gall-bladder. 23. Its neck. 24. Lobulus quartus. 25 Lobulus Spigelii. 26. Lobulus caudatus. 27. Inferior vena cava. 28. Curvature of liver to fit ascending colon. 29. Depression to fit right kidney. 30. Upper portion of its right concave surface over renal capsule. 31. Portion of liver uncovered by peritoneum. 32. Inferior edge of coronary ligament in the liver. 33. Depression made by vertebral column.

[1] Philosophical Transactions for 1833, p. 711.

the vena portæ; according to others, with radicles of the hepatic artery; whilst others have considered, that the radicles of the hepatic ducts have blind extremities, and that the capillary bloodvessels, which secrete the bile, ramify on them. This last arrangement of the biliary apparatus was well shown in an interesting case, which fell under the care of Professor Hall, in the Baltimore Infirmary, and was examined after death in the author's presence. The particulars have been detailed, with some interesting remarks by Professor Geddings.[1] In this case, in consequence of cancerous matter obstructing the ductus communis choledochus, the whole excretory apparatus of the liver was enormously distended; the common duct was dilated to the size of the middle finger: at the point where the two branches that form the hepatic duct emerge from the gland, they were large enough to receive the tip of the middle finger; and as they were proportionally dilated to their radicles in the intimate tissue of the liver, their termination in a blind extremity was clearly exhibited. These blind extremities were closely clustered together, and the ducts, proceeding from them, were seen to converge, and terminate in the main trunk for the corresponding lobe. At their commencement, the excretory ducts are termed *pori biliarii.* These ultimately form two or three large trunks, which issue from the liver by the transverse fissure, and end in the *hepatic duct.* 4. *Lymphatic vessels.* 5. *Nerves*, in small number, compared with the size of the organ, some proceeding from the eighth pair; but the majority from the solar plexus, which follow the course and divisions of the hepatic artery. 6. *Supra-hepatic veins* or *venæ cavæ hepaticæ*, which arise in the liver by imperceptible radicles, communicating, according to common belief, with the final ramifications of both the hepatic artery and vena portæ; according to Mr. Kiernan occupying the centre of the lobules, and hence termed *intralobular veins—venulæ intralobulares* seu *centrales.* They return the superfluous blood, carried to the liver by these vessels, by means of two or three trunks, and six or seven branches, which open into the vena cava inferior. These veins generally pass, in a convergent manner, towards the posterior margin of the liver, and cross the divisions of the vena portæ at right angles. 7. The remains of the umbilical vein, which, in the fœtus, enters at the horizontal fissure. This vein, after respiration is established, becomes converted into a ligamentous substance, called, from its shape, *ligamentum rotundum* or *round ligament.* It is difficult to describe the parenchyma or substance formed by these anatomical elements; and, although the term *liver-coloured* is used in common parlance, it is not easy to say what are the ideas attached to it.

Fig. 335.



Lobules of Liver.

The views of Mr. Kiernan in regard to the intimate structure of the liver, which have been embraced by so many anatomists, may be understood by the accompanying illustrations, taken from his communications on the subject. The

[1] North American Archives of Medical and Surgical Science, for June, 1835, p. 157.

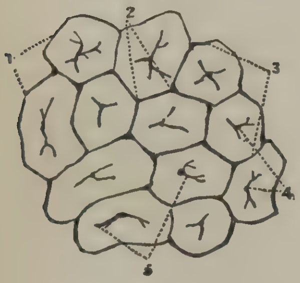
acini, to which allusion has been made, are termed by him *lobules*. Fig. 335, 1, exhibits some of the cells of which the lobules are composed, seen under a magnifying power of 200 diameters. 2, represents a longitudinal section of a lobule with ramifications of the hepatic vein: and Fig. 336, the connexion of the lobules with the same vein;—the centre of each being occupied by a venous twig—or intralobular vein. Fig. 337 represents the lobules as seen on the surface of the liver when divided transversely. In this, 2, exhibits the interlobular spaces; 3, interlobular fissures; 4, intralobular veins occupying the centres of the lobules; and 5, smaller veins terminating in the central veins. Fig. 338, is a similar section of three lobules, showing the arrangement of the two principal systems of bloodvessels; 1, 1, intralobular veins; and 2, 2, interlobular plexus

Fig. 336.

Connexion of Lobules of Liver with Hepatic Vein.

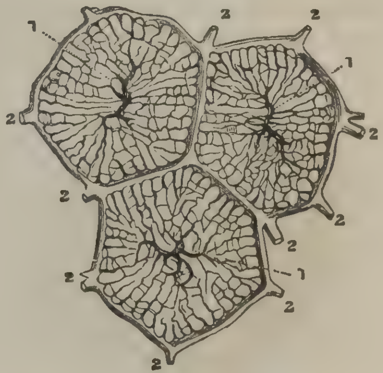
1. Hepatic vein. 2, 2, 2. Lobules, each containing an intralobular or hepatic twig.

Fig. 337.



Transverse Section of Lobules of the Liver.

Fig. 338.



Horizontal Section of three Superficial Lobules, showing the two principal Systems of Bloodvessels.

formed by branches of the vena porta. Fig. 339 represents a horizontal section of two superficial lobules, showing the *interlobular plexus of biliary ducts:* 1, 1, intralobular veins; 2, 2, trunks of biliary ducts, proceeding from the plexus, which traverses the lobules; 3, interlobular tissue; and 4, parenchyma of the lobules. The interlobular biliary ducts ramify upon the capsular surface of the lobules; and then enter their substance and are supposed to subdivide into minute branches, which by anastomoses with each other form the reticulated plexus depicted in Fig. 339, called by Mr. Kiernan the *lobular biliary plexus*.

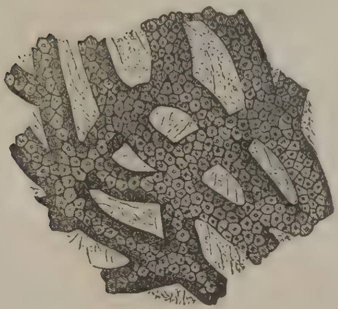
It is from this arrangement of the bloodvessels and biliary ducts, that Mr. Kiernan infers that bile must be secreted from the portal

Fig. 339.

Horizontal Section of two Superficial Lobules, showing Interlobular Plexus of Biliary Ducts.

vessels;—the intralobular ramifications of the hepatic veins conveying back to the heart the blood which has been inservient to the secretion. The views of Mr. Kiernan have been generally adopted by anatomists. Wagner, however, whilst he regards the beautiful figures and descriptions of Mr. Kiernan as the best he has seen, asserts, that they very certainly also include many mistakes; whilst Krause "combats the views of Kiernan, holding them to be hypothetical;"[1] and E. H. Weber[2] and Kronenberg[3] oppose them. The chief point, according to Mr. Paget, in which these gentlemen differ from Mr. Kiernan, is in denying that the component parts of the liver are arranged in lobules. They, with Henle and Mr. Bowman, describe the capillary networks as solid,—that is as extending uniformly through the liver. They, also, deny the existence of fibro-cellular partitions dividing the liver into lobules as maintained by Mr. Kiernan and J. Müller;[4] and even the existence of more fibro-areolar tissue than serves to invest the larger vessels, &c., of the organ. They likewise deny that there are any such interlobular veins and fissures as Mr. Kiernan describes, and state, that the smaller branches of these veins communicate by branches only just larger, if at all larger, than capillaries.[5]

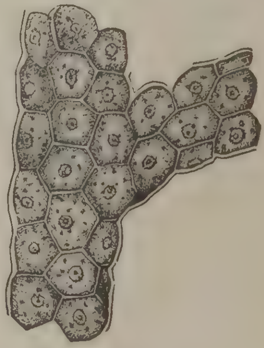
Fig. 340.



A small portion of a Lobule highly magnified. (Leidy.)

The secreting cells are seen within the tubes, and in the interspaces of the latter the fibrous tissue is represented.

Fig. 341.



Portion of a Biliary Tube, from a fresh Human Liver, very highly magnified. (Leidy.)

The secreting cells may be noticed to be polygonal from mutual pressure.

[1] Wagner, Elements of Physiology, by R. Willis, § 195, Lond., 1842.
[2] Müller's Archiv., 1844, Heft 3. [3] Ibid. [4] Ibid.
[5] See, on all this subject, Professor Theile, art. Leber, Wagner's Handwörterbuch der Physiologie, 9te Lieferung, s. 308, Braunschweig, 1845.

Histologically considered, the liver may be regarded as consisting of ramifications of excretory ducts, surrounded by bloodvessels, which afford the materials for secretion, and of cells which elaborate it, but as respects the precise arrangement of the cells anatomists are not wholly in accordance. Dr. Leidy[1] affirms, that they line the inner surface of the tubuli that form the biliary plexus of Kiernan; that they are irregularly angular or of a polygonal shape, owing to their pressing upon each other; and contain a fine granular matter, oil globules, a granular nucleus and transparent nucleolus,—the oil globules, under special circumstances of diet and disease, experiencing considerable increase. Dr. C. Handfield Jones[2] has, however, recently maintained, that the ramifications of the hepatic ducts do not enter the lobules as maintained by Mr. Kiernan, but are confined to the interlobular spaces,—the substance of the lobules being composed of secreting parenchyma and bloodvessels; and that the action of the liver seems to consist in the transmission of the bile, as it is formed, from cell to cell, until

Fig. 342.

Hepatic Cells gorged with Fat.

a. Atrophied nucleus. *b*. Adipose globules.

Fig. 343.

Minute Portal and Hepatic Veins and Capillaries.

a, *a*. Twigs of the portal vein. *d*. Twig of the hepatic vein. *b*. Intermediate capillaries.

it arrives in the neighbourhood of the excretory ducts by which it is absorbed.

Perhaps the best mode, according to Br. Budd,[3] to get a general

[1] American Journal of the Medical Sciences, p. 1, Jan., 1848; and Quain's edition of Quain and Sharpey's Human Anatomy, ii. 487, Philad., 1849.

[2] Philosophical Transactions, Pt. i., for 1849.

[3] On Diseases of the Liver, Amer. edit., p. 17, Philad., 1846.

idea of the structure of the liver is to examine under the microscope, —*first*, a thin slice of liver, in which the portal and hepatic veins are thoroughly injected; and *secondly*,—a small particle taken from the lobular substance of a fresh liver, in which the bloodvessels are empty, as in an animal killed by bleeding. Figure 343, from a specimen by Mr. Bowman, represents, on a magnified scale, a small branch of the hepatic vein, two or three branches of the portal vein, and the intermediate capillaries. The capillaries appear to have nearly the same relation to the branches of the portal vein as they have to those of the hepatic. It is difficult to tell, from this specimen, which branch is portal and which hepatic,—the smaller branches of both being, as it were, hairy with capillaries springing directly from them on every side, and forming a close and continuous network. Dr. Budd thinks, that the injected preparations of Mr. Bowman show clearly, that the opinion of Malpighi, Kiernan, Müller, and others, that the lobules are isolated from each other, each being invested by a layer of areolar tissue, is erroneous; and that the lobules are not dis-

Fig. 344.

Lobules of the Liver magnified.

a, a, a. Minute twigs of the portal vein. *b, b, b*. Capillaries immediately springing from them, and serving with them to mark the outline of the lobules. *d, d, d*. Capillaries in the centre of the lobules, injected through the hepatic vein. *e, e*. Places at which the size injected into the portal vein has met that injected into the hepatic vein, so that all the intermediate capillaries are coloured and conspicuous. *l, l*. Centres of lobules into which the injection has not passed through the hepatic vein.

tinct, isolated bodies, but merely small masses, tolerably defined by the ultimate twigs of the portal vein, and the injected or uninjected

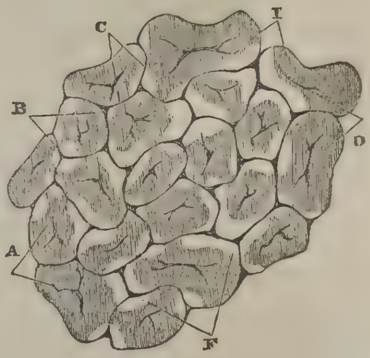
capillaries immediately contiguous to them. The lobules, according to Dr. Budd, appear only as distinct isolated bodies when seen by too low a magnifying power to clearly distinguish the capillaries. The real nature of the lobules, and the manner in which they are formed, will perhaps be better understood, he thinks, by reference to the illustration, (Fig. 344,) for which he expresses his indebtedness to Mr. Bowman. It represents, on a magnified scale, six lobules of the liver, and was made from a drawing under the microscope of a section of the liver of a cat, partially injected through the portal vein, and also through the hepatic.

Mr. Kiernan has deduced interesting pathological inferences from the anatomical arrangement of the liver which he conceives to exist;

Fig. 345.

First Stage of Hepatic Venous Congestion. (Kiernan.)

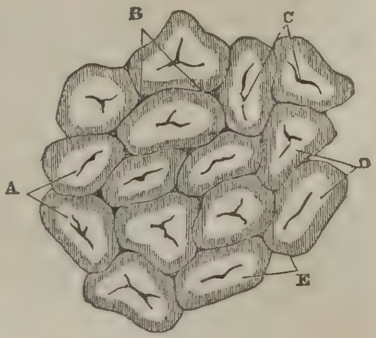
Fig. 346.



Second Stage of Hepatic Venous Congestion. (Kiernan.)

thus, he considers that the lobules may be congested by accumulation of blood in the hepatic or in the portal venous system; which may be detected by a minute inspection of the lobules. The precise causes of this are referred to in another work.[1] The accompanying illustrations will be sufficient here. Fig. 345 represents the lobules in the *first stage* of what he terms *hepatic venous congestion* or congestion of the terminations of the hepatic vein: 2, the interlobular spaces and fissures. In Fig. 346, the lobules are in the second stage of congestion. B and C, the interlobular spaces; D, congested intra-

Fig. 347.



Portal Venous Congestion.

B. Interlobular spaces and fissures. C. Intralobular veins. D. Anæmic portions. E. Congested portions. (Kiernan.)

[1] Practice of Medicine, 3d edit., vol. ii. chap. 3, Philad., 1848.

lobular or hepatic veins; I, congested patches extending to the circumference of the lobules; F, uncongested portions. In Fig. 347, the lobules are in a state of *portal venous congestion*; not a common occurrence. It has been seen by Mr. Kiernan in children only.

The view of Mr. Kiernan has been held to explain also the diversity of the statement of anatomists as to the relative position of the *red* and *yellow* substances, which have been considered to compose the liver: the red is the congested portion of the lobules, whilst the yellow is the non-congested portion in which the biliary plexus appears more or less distinctly.

Fig. 348.

The three Coats of Gall-bladder separated from each other.

1. External or peritoneal coat. 2. Areolar coat with its vessels injected. 3. Mucous coat covered with wrinkles. 4, 4. Valves, formed by this coat in the neck of gall-bladder. 5, 5. Orifices of mucous follicles at this point.

The liver has two coats;—the outer, derived from the peritoneum, which is very thin, transparent, easily lacerable, and vascular, and is the seat of the secretion effected by serous membranes in general. It does not cover the posterior part, or the excavation for the gall-bladder, the vena cava, or the fissures in the concave surface of the liver. The inner coat is the proper membrane of the liver. It is thin, but not easily torn, and covers not only every part of the surface of the liver, but the large vessels that are proper to the organ. The condensed areolar substance,—which unites the sinus of the vena portæ and its two great branches, the hepatic artery, common biliary duct, lymphatic glands, lymphatic vessels, and nerves in the transverse fossa or fissure of the liver,—was described by Glisson as a capsule; and hence has been called *capsule of Glisson*. It connects the various anatomical elements of the liver together.

Fig. 349.

Gall-bladder distended with Air, and with its Vessels injected.

1. Cystic artery. 2. Branches of it which supply the peritoneal coat of the liver. 3. Branch of the hepatic artery which goes to gall-bladder. 4. Lymphatics of gall-bladder.

The *gall-bladder* (Figs. 300 and 348) is a small membranous pouch of a pyriform shape, situate at the inferior and concave surface of the liver to which it is attached;

and above the colon and duodenum. A quantity of bile is usually found in it. It is not met with in all animals; is wanting in the elephant, horse, stag, camel, rhinoceros, and goat; in certain of the cetacea; in some birds, as the ostrich, pigeon, and parrot; and is occasionally so in man. No traces of it are met with in the invertebrata. It may be looked upon as a dilatation of the gall-ducts, and adapted for the reception and retention of bile. Its largest part or *fundus* is turned forwards; and, when filled, frequently projects beyond the anterior margin of the liver. Its narrowest portion, cervix or neck, is turned backwards, and terminates in the cystic duct. Externally, it is partly covered by the peritoneum, which attaches it to the liver, and to which it is, moreover, adherent by areolar tissue and vessels. Internally, it is rugous; the folds being reticulated, and appearing somewhat like the cells of a honeycomb.

Anatomists have differed with regard to the number of coats proper to the gall-bladder. Some have described two only;—the peritoneal and mucous; others have added an intermediate areolar coat; whilst others have reckoned four;—a peritoneal,—a thin stratum of muscular fibres passing in different directions, and of a pale colour,—an areolar coat, in which a number of bloodvessels is situate, and an internal mucous coat. The existence of the muscular coat has been denied by perhaps the generality of anatomists; but there is reason for believing in its existence. Amussat saw muscular fibres distinctly in a gall-bladder dilated by calculi; and Dr. Monro (Tertius),[1] Professor of Anatomy in the University of Edinburgh, asserts, that he has seen it contract, in a living animal, for half an hour, under mechanical irritation, and assume the shape of an hour-glass. The mucous coat forms the rugæ to which we have already alluded. In the neck, and beginning of the cystic duct, there are from three to seven—sometimes twelve—semilunar duplicatures, which retard the flow of any fluids inwards or outwards. These are sometimes arranged spirally, so as to form a kind of valve, according to M. Amussat.[2]

On the inner surface of the gall-bladder, especially near its neck, numerous follicles exist, the secretion from which is said to fill the gall-bladder, when that of the bile has been interrupted by disease, as in yellow-fever, scirrhus of the liver, &c. The *hepatic duct* is the common trunk of all the excretory vessels of the liver; and makes its exit from that organ by the transverse fissure. It is an inch and a half in length, and about the diameter of an ordinary writing-quill. It is joined, at a very acute angle, by the duct from the gall-bladder—*cystic duct*—to form the ductus communis choledochus. The cystic duct is about the same length as the hepatic. The *ductus communis choledochus* is about three, or three and a half inches long. It descends behind the right extremity of the pancreas, through its substance; passes for an inch obliquely between the coats of the duodenum, diminishing in diameter; and ultimately terminates by a yet more contracted orifice on the inner surface of the intestine, at the

[1] Elements of the Anatomy of the Human Body, Edinb., 1825.
[2] Magendie, Précis, &c., ii. 464.

distance of three or four inches from the stomach. The structure of all these ducts is the same. The external coat is thick, dense, strong, and generally supposed to be of an areolar character; the inner is a mucous membrane, like that which lines the gall-bladder.

The secretion of bile is probably effected like that of other glandular organs; modified, of course, by the peculiar structure of the liver. We have seen, that the organ differs from every other secretory apparatus, in having two kinds of blood distributed to it;—arterial by the hepatic artery; and venous by the vena portæ. A question has consequently arisen—from which of these is the bile formed? Anatomical inspection does not positively settle the question; and, accordingly, argument is all that can be adduced on one side or the other. The most common and the oldest opinion is, that the bile is separated from the blood of the vena portæ; and the chief reasons brought forward in favour of the belief, are the following: *First.* The blood of the portal system is better adapted than arterial blood for the formation of bile, on account of its having, like all venous blood, more carbon and hydrogen, which are necessary for the production of a humour as fat and oily as the bile; and, as the experiments of Schultz[1] and others have proved, that portal blood contains more fat than that of other veins and arteries, it has been imagined, by some, that the blood, in crossing the omentum, becomes loaded with fat. *Secondly.* The vena portæ ramifies in the liver after the manner of an artery, and evidently communicates with the secretory vessels of the bile. *Thirdly.* It is larger than the hepatic artery; and more in proportion to the size of the liver; the hepatic artery seeming to be merely for the nutrition of the liver, as the bronchial artery is for that of the lung.

In answer to these positions, it has been argued. *First.* That there seems to be no more reason why the bile should be formed from venous blood than other fatty and oleaginous humours,—marrow and fat for example,—which are derived from arterial blood. It is asked, too, whether, in point of fact, the blood of the vena portæ is more rich in carbon and hydrogen? and whether there be a closer chemical relation between bile and the blood of the vena portæ, than between fat and arterial blood? The notion of the absorption of fat from the omentum, it is properly urged, is totally gratuitous. *Secondly.* The vena portæ does not exist in the invertebrated animals; and yet, in a number of them, there is an hepatic apparatus, and a secretion of bile. *Thirdly.* Admitting that the vena portæ is distributed to the liver after the manner of an artery; is it clear, it has been asked, that it is inservient to the biliary secretion? *Fourthly.* If the vena portæ be more in proportion to the size of the liver than the hepatic artery, the latter appears to bear a better ratio to the quantity of bile secreted: and, *Lastly.* It is probable, as has been shown in another place, that the liver has other functions connected with the portal system, in the admixture of heterogeneous liquids absorbed from the intestinal canal; and, it may be, in depriving the blood of the vena portæ of principles

[1] Rust's Magazine, B. xliv.; or Gazette Médicale, Aug. 15, 1835.

which go to the formation of bile and might be unfit for assimilation, if transported into the blood of the general system.

In the absence of accurate knowledge derived from direct experiment, physiologists have usually embraced one or other of these exclusive views. The generality, as we have remarked, assign the function to the vena portæ. Bichat, on the other hand, ascribes it to the hepatic artery. M. Broussais[1] thinks it probable, that the blood of the vena portæ is not foreign to the formation of bile, since it is confounded with that of the hepatic artery in the parenchyma of the liver; "but to say with the older writers, that the bile can only be formed from venous blood, is, in our opinion," he remarks, "to advance too bold a position, since the hepatic arteries send branches to each of the glandular acini, that compose the liver." M. Magendie likewise concludes, that nothing militates against the idea of both kinds of blood participating in the secretion; and that it is supported by anatomy, as injections prove, that all the vessels of the liver,—arterial, venous, lymphatic, and excretory,—communicate with each other. Mr. Kiernan, as we have seen, considers that the blood of the hepatic artery, after having nourished the liver, is inservient to the secretion, but not until it has become venous, and entered the portal veins. He,—with all those that coincide with him in the morphological arrangement of the liver—denies that there is any communication between the ducts and bloodvessels; and asserts, that if injections pass between them, it is owing to the rupture of the coats of the vessels. Experiments on pigeons, by M. Simon,[2] of Metz, showed, that when the hepatic artery was tied, the secretion of bile continued, but that if the portal and hepatic veins were tied, no trace of bile was subsequently found in the liver. It would thence appear, that in these animals the secretion of bile takes place from venous blood. But inferences from the ligature of those vessels have been very discordant. In two cases, in which Mr. Phillips tied the hepatic artery, the secretion of bile was uninterrupted, yet the same thing was observed in three other cases, in which the ligature was applied to the trunk of the vena portæ.

The view, that ascribes the bile to the hepatic artery, has always appeared to the author the most probable. It has all analogy in its favour. There has been no disputed origin as regards the other secretions, excepting, of late, in the case of the urinary. All proceed from arterial blood; and function sufficient, we have seen, can be assigned to the portal system, without conceiving it to be concerned in the formation of bile. We have, moreover, morbid cases, which would seem to show that bile can be formed from the blood of the hepatic artery. Mr. Abernethy[3] met with an instance, in which the trunk of the vena portæ terminated in the vena cava; yet bile was found in the biliary ducts. A similar case is given by Mr. Lawrence;[4] and Professor Monro[5] details a case communicated to him by the late Mr.

[1] Traité de Physiologie, &c., Drs. Bell's and La Roche's translation, 3d edit., p. 456, Philad., 1832.

[2] Edinburgh Med. and Surg. Journal, xc. 229.

[3] Philosoph. Transact., vol. lxxxiii.

[4] Medico-Chirurgical Transact., iv. 174.

[5] Elements of Anatomy, Edinb., 1825.

Wilson, then of the Windmill Street School, in which there was reason to suppose, that the greater part of the bile had been derived from the hepatic artery. The patient, a female, thirteen years old, died from the effects of an injury of the head. On dissection, Mr. Wilson found a large swelling at the root of the mesentery, consisting of several absorbent glands in a scrofulous state. Upon cutting into the mass, he accidentally observed a large vein passing directly from it into the vena cava inferior, which on dissection, proved to be the vena portæ; and on tracing the vessels entering into it, one proved to be the inferior mesenteric vein: and another, which came directly to meet it, from behind the stomach, proved to be a branch of the splenic vein, but somewhat larger, which ran upwards by the side of the vena cava inferior, and entered that vein immediately before it passes behind the liver. Mr. Wilson traced the branches of the trunk of the vessel corresponding to the vena portæ sufficiently far in the mesentery and mesocolon to be convinced, that it was the only vessel that returned the blood from the small intestines, and from the cæcum and colon of the large intestines. He could trace no vein passing into the liver at the cavity of the porta; but a small one descended from the little epiploon, and soon joined one of the larger branches of the splenic vein. The hepatic artery came off in a distinct trunk from the aorta, and ran directly to the liver. It was much larger than usual. The greater size of the hepatic artery, in this case, would favour the idea, that the arterial blood had to execute some office, that ordinarily belongs to the vena portæ. Was this the formation of bile? The case seems, too, to show, that bile can be formed from the blood of the hepatic artery.

Professor Gintrac[1] has published a case in which there was ossification with obliteration of the vena portæ. The patient died of ascites. The liver was pale or whitish, and irregularly wrinkled or mammillated on its surface. The gall-bladder contained a medium quantity of thickish yellow bile. The biliary ducts were normal. The vena portæ above the junction of the splenic and superior mesenteric veins was completely filled by an old clot, which adhered to the inner membrane. The clot was solid, and of a deepish black colour. At the same part of the vein several osseous plates were observed many lines in diameter, which were situate between the inner and middle coats of the vein, without having much adherence to either. All the abdominal veins that ended in these vessels were gorged with blood, and varicose. Professor Gintrac ascribed the ascites to the obliteration and ossification of the vena portæ, and he considered the case to prove, that although obliteration of that vessel probably modified the secretion of bile, it did not prevent it altogether; but interfered materially with the nutrition of the liver. Hence, he inferred, that the blood of the vena portæ contributes to the nutrition of the liver; but is not indispensable to the secretion of bile.

In Professor Hall's patient,[2] the vena portæ and its bifurcation were completely filled with encephaloid matter, so that no blood could pass

[1] Cited in Amer. Journal of the Med. Sciences, Oct., 1844, p. 476. [2] P. 304.

through it to the liver; the secretion of bile could not, consequently, have been effected through its agency. It has been presumed, however, that in such cases, portal blood might still enter the liver through the extensive anastomoses, which Professor Retzius,[1] of Stockholm, found to exist between the abdominal veins. That gentleman observed, when he tied the vena portæ near the liver, and threw a coloured injection into the portion below the ligature, that branches were filled, some of which, proceeding from the duodenum, terminated in the vena cava; whilst others, arising from the colon, terminated in the left emulgent vein. In subsequent investigations, he observed an extensive plexus of minute veins ramifying in the areolar tissue on the outer surface of the peritoneum, part of which was connected with the vena portæ, whilst the other terminated in the system of the vena cava. In a successful injection, these veins were seen anastomosing very freely, in the posterior part of the abdomen, with the colic veins, as well as with those of the kidneys, pelvis, and even the vena cava. The arrangement, pointed out by Retzius, accounts for the mode in which the blood of the abdominal venous system reaches the cava, when the vena portæ is obliterated from any cause; and it shows the *possibility* of portal blood reaching the liver so as to be inservient to the biliary secretion, but does not, we think, exhibit the *probability*.

Still more recently, cases of obliteration of the vena portæ have been recorded, in which the nutrition of the liver was materially impaired, so that the organ had become atrophied, whilst the secretion of bile persisted. Such a case is given by M. Raikem,[2] of Brussels. In this, the vein was entirely obliterated by clots of blood intimately adherent to its inner surface. The liver was smaller than usual; the gall-bladder contained a large quantity of serous bile of a yellowish and orange colour, and the cystic and hepatic ducts were filled with it. The trunk of the hepatic artery was three lines in diameter, and contained no clots of blood; and such was the case with the supra-hepatic veins. Whence M. Raikem concludes, that in the present state of physiological knowledge, there are reasons sufficiently conclusive for the opinion, that the hepatic artery is capable alone of furnishing to the liver the materials necessary for the secretion of bile, when the vena porta is obliterated to so great a degree as not to allow the blood to be conveyed through it to the organ; and, he asks, as the result of observations of numerous pathological cases, whether "it is indeed proved, as is generally believed, that the hepatic artery is alone charged with the function of nourishing the liver to the exclusion of the portal vein," when "we observe that the liver is atrophied in those in whom the portal vein has been entirely obliterated for a long time?" An additional case of the kind has been detailed by Dr. Craigie.[3] In this, the vein was found completely filled and distended by firm, yet compressible, elastic matter, as if the vessel had been injected, so that its diameter was fully one inch. Of the

[1] Ars Berättelse af Setterblad, 1835, s. 9; cited in Zeitschrift für die Gesammte Heilkunde, Feb., 1837, s. 251.

[2] Mémoires de l'Académie Royale de Médecine de Belgique, tom. i., Bruxelles, 1848; translated in the Edinb. Med. and Surg. Journal, April, 1850, p. 350.

[3] Edinb. Med. and Surg. Journal, April, 1850, p. 512.

effects of this obliteration, the most remarkable, again, was the atrophy of the liver, which was not more than one-third of its usual size. A small quantity of light coloured bile was found in the gall-bladder, and during life the fæces had the usual colour. "M. Raikem," says Dr. Craigie, "has adverted to the notion so much favoured by various physiological speculators, that the hepatic artery is employed in maintaining the nutrition of the liver, while to the portal vein belongs the function of conveying to the gland the materials from which bile is to be prepared; and to show its incompetency, has adduced several conclusive arguments. It is scarcely possible to conceive a stronger argument against it than is furnished by the facts of this case. The portal vein was completely obstructed, and no blood must for a long time have been conveyed through its branches into the gland. The liver is likewise very much reduced in size, not, indeed, uniformly and equally in all its parts, but still so much and so generally atrophied, that it is difficult to ascribe the diminution and wasting of parts to any other cause. The two circumstances, therefore, appear to stand in the relation of cause and effect." It is to be regretted that the history of this case is rendered imperfect by the circumstance, that "the state of the hepatic artery was not ascertained."

It would seem, then, that the portal system is not absolutely necessary to the formation of bile; yet a modern writer[1] considers it "a most puerile question" to ask whether the secretion can be effected from venous blood! "Had not," he adds, "secretion been destined to take place from the blood of the vena portarum, nature would not have been at the pains to distribute it through the liver; the peculiar arrangement is already an answer to the question; the end of it is, as I have said, to economise arterial blood." As before remarked, however, a sufficient function can be assigned to the portal system without supposing that it has any agency in the secretion of bile. Still, there is nothing inconsistent with the idea, that both kinds of blood may be inservient to the secretion. Mention has been made elsewhere,[2] that MM. Bouchardat and Sandras, having fed herbivorous animals on farinaceous substances, detected more dextrin, grape sugar, and lactic acid in the blood of the vena portæ than in that of any other vessel; and that Trommer discovered grape sugar in the blood of the portal vein, but not in that of the hepatic veins of animals with whose food that substance had been mixed. Moreover, MM. Blondlot[3] and Chossat[4] found, that the administration of non-nitrogenous articles of food, especially of sugar, considerably increased the amount of bile secreted. All these circumstances certainly lead to the belief, that nitrogenized aliments, absorbed by the veins of the stomach and intestines, may supply materials, which may go to the formation of bile.

When bile is once formed in the tissue of the liver, it is received into the minute excretory radicles, whence it proceeds along the ducts until, from all quarters, it arrives at the hepatic duct. A difference of senti-

[1] Dr. R. Willis, London and Edinb. Monthly Journal of Med. Science, Sept., 1841, p. 628.
[2] Vol. i. p. 601.
[3] Essai sur les Fonctions du Foie, p. 62, Paris, 1846.
[4] Gazette Médicale de Paris, Oct., 1843.

ment exists regarding the course of the bile from the liver and gall-bladder to the duodenum. According to some, it is constantly passing along the choledoch duct; but the quantity is not the same during digestion as at other times. In the intervals of digestion a part only of the bile attains the duodenum; the remainder ascends along the cystic duct, and is deposited in the gall-bladder. During digestion, however, not only the whole of the newly secreted bile arrives at the duodenum, but that which had been collected in the interval is evacuated into the intestine. In support of this view it is affirmed, that bile is always met with in the duodenum; and that the gall-bladder always contains more bile when abstinence is prolonged, and is empty immediately after digestion.

The great difficulty has been, to explain how the bile gets into the gall-bladder; and in what manner it is expelled from that reservoir. In many birds, reptiles, and fishes, the hepatic duct and cystic duct open separately into the duodenum; whilst ducts, called *hepato-cystic*, pass directly from the liver to the gall-bladder. In man, however, the only visible route, by which it can reach that reservoir, is by the cystic duct, the direction of which is retrograde; and, consequently, the bile in the erect attitude has to ascend against gravity. The spiral valve of M. Amussat has been presumed to act like the screw of Archimedes, and to facilitate the entrance of the refluent bile; but this appears to be imaginary. It is, indeed, impossible, to see any analogy between the corporeal and the hydraulic instrument. The arrangement of the termination of the choledoch duct in the duodenum has probably a more positive influence. The embouchure is the narrowest part of the duct; the ratio of its calibre to that of the hepatic duct having been estimated at not more than one to six, and to the calibre of its own duct as one to fifteen. This might render it impracticable for the bile to flow into the duodenum as promptly as it arrives at the embouchure; and, in this way collecting in the duct, it might reflow into the gall-bladder. M. Amussat, indeed, affirms, that this can be demonstrated on the dead body. By injecting water or mercury into the upper part of the hepatic duct, the injected liquid was found to issue both by the aperture into the duodenum, and by the upper aperture of the cystic duct into the gall-bladder.

With regard to the mode in which the gall-bladder empties itself during digestion, it is probably by a contractile action. We have seen, that it has not usually been admitted to possess a muscular coat, but that it is manifestly contractile. The chyme, as it passes into the duodenum, excites the orifice of the choledoch duct; this excitement is propagated along the duct to the gall-bladder, which contracts; but according to M. Amussat does not evacuate its contents suddenly; for the different planes of the spiral valve are applied against each other, and only permit the flow to take place slowly. This he found was the case in the dead body, when water was injected into the gall-bladder, and then passed out through the cystic duct. Other physiologists have presumed, that although the bile is secreted in a continuous manner, it only flows into the duodenum during chylification; at other times, the choledoch duct is contracted, so that the bile is compelled to reflow

through the cystic duct into the gall-bladder; and it is only when the gall-bladder is filled, that it passes freely into the duodenum. Independently, however, of other objections to this view, vivisections have shown, that if the orifice of the choledoch duct be exposed, whatever may be the circumstances in which the animal is placed, the bile is seen issuing *guttatim* at the surface of the intestine. That the flow of bile from the gall-bladder, however, is dependent upon the presence of aliment in the intestines, is shown by the fact, that the reservoir is almost always found turgid in those who have died from starvation; the secretion formed at the ordinary slow rate having gradually accumulated for want of demand. This fact, it has been properly remarked, is important in juridical inquiries.

The biliary secretion, which proceeds immediately from the liver—*hepatic bile*—differs from that obtained from the gall-bladder,—*cystic bile*. The latter possesses greater bitterness; is thicker, of a deeper colour; and is that which has been usually analyzed. It is of a yellowish-green colour; viscid; and slightly bitter. It combines readily with water in all proportions; mixes freely with oil or fat; and foams, when stirred, like soapy water. It is, indeed, in common use in the same way as soap for cleansing articles of dress, and especially for taking out grease. Its chemical properties have been frequently examined; yet much is still needed, before we can consider the analysis satisfactory. Cystic bile has been generally supposed to have an alkaline reaction; but M. Bouisson, Dr. Kemp, and Von Gorup-Besanez,[1] who examined it, state, that when fresh and perfectly healthy, it is neutral. The last observer found it at first neutral; but in the early periods of its decomposition it is apt to become acid, and afterwards alkaline. The effects of bile, however, on test papers, are difficult to appreciate, on account of the yellow stain it gives them. It has been examined by Boerhaave, Verheyen, Baglivi, Hartmann, Macbride, Ramsay, Gaubius, Cadet, Fourcroy, Maclurg, Thénard, Berzelius, Chevreul, Leuret and Lassaigne, Frommherz and Gugert, Schultz, Vogel, John, Treviranus, Tiedemann and Gmelin, Bouisson, Liebig, Kemp, Platner, Frerichs, Von Gorup-Besanez, Mulder, Bensch, Strecker, &c., &c. Thénard's[2] analysis of 1100 parts of human bile is as follows:—water, 1000; albumen, 42; resinous matter, 41; yellow matter, (*cholepyrrhin, biliphœin*), 2 to 10; free soda, 5 or 6; phosphate and sulphate of soda, chloride of calcium, phosphate of lime, and oxide of iron, 4 or 5. According to M. Chevallier, it contains also a quantity of picromel or *bilin*. Berzelius[3] called in question the correctness of M. Thénard's analysis, and gave the following:—water, 908·4; bilin, 80; albumen, 3·0; soda, 4·1; phosphate of lime, 0·1; common salt, 3·4; phosphate of soda, with some lime, 1·0. His analysis of ox-gall gave, water, 928·380; solid constituents, 71·620; bilin, 50·000; chloride of sodium, lactate of soda, and extractive matter soluble in alcohol, 4·334; cholesterin, ·001; mucus, 2·350. In a more recent essay[4] he gives the proportions as follows:—water, 90·44; bilin, 8·00; mucus of the gall-

[1] Untersuchungen über Galle, s. 17, Erlangen, 1846.
[2] Mém de la Société d'Arcueil, i. 38, Paris, 1807.
[3] Medico-Chirurgical Transactions, iii. 241.
[4] Art. Galle, Handwörterbüch der Physiologie, 3te Lieferung, s. 518, Braunschweig, 1842.

bladder, 0·30; alkali associated with bilin, 0·41; chloride of sodium; alkaline lactate, and extractive matters, 0·74; phosphate of soda and phosphate of lime, 0·11. The results of Dr. Davy's[1] analysis of healthy bile were as follows:—water, 86·0; resin of bile, 12·5; albumen, 1·5. The experiments of Gmelin, for which he is highly complimented by Berzelius,[2] although the latter considers, that some of the products may have been formed by the reaction of elements upon each other—yielded the following results:—an odorous material, like musk; cholesterin; oleic acid; margaric acid; cholic acid; resin of bile; taurin (gallen-asparagin); bilin; colouring matter; osmazome; a substance which, when heated, had the odour of urine; another resembling bird-lime, gleadin; albumen (?); mucus of the gall-bladder; casein, or a similar substance; ptyalin, or a similar matter; bicarbonate of soda; carbonate of ammonia; acetate of soda; oleate, margarate, cholate, and phosphate of potassa and soda; chloride of sodium, and phosphate of lime. Cadet[3] considered bile as a soap with a base of soda, mixed with sugar of milk,—a view, which Raspail,[4] Demarçay,[5] Liebig and others think, harmonizes most with observed facts. Every other substance met with in the bile, M. Raspail looks upon as accessory. M. Demarçay regards it as a soda salt; and regards the essential constituents to be an oily acid, which he terms *choleic*, and soda, which exists in a state of combination with it. Again, it has been analyzed by Muratori,[6] who assigns it the following constituents;—water, 832; peculiar fatty matter, 5; colouring matter, 11; cholesterin combined with soda, 4; picromel of Thénard, 94·86; osmazome (*estratto di' carne*), 2·69; mucus, 37; soda, 5·14; phosphate of soda, 3·45; phosphate of lime, 3; and chloride of sodium, 1·86. Von Gorup-Besanez,[7] who found oxide of iron as a common constituent of the ashes of the bile, states, that copper can generally be detected in it in health; and constantly in biliary calculi.

One of the most recent analyses of human bile is given by Frerichs.[8] It was obtained from healthy men killed by severe accidents. The following is one analysis:—water, 86·00; solid constituents, 14·00; bilate of soda [choleate of soda?] 10·22; cholesterin, 0·16; margarin and olein, 0·32; mucus, 2·66; chloride of sodium, 0·25; tribasic phosphate of soda, 0·20; basic phosphate of lime, basic phosphate of magnesia, 0·18; sulphate of lime, 0·02; peroxide of iron, traces.

The proportion of solid matter in the bile is usually from 9 to 12 per cent., nearly the whole of which consists of cholesterin and bilin. Cholesterin is almost altogether composed of carbon and hydrogen. Bilin contains nitrogen.

One cause of the discrepancies in the analyses of bile is considered to be the facility with which it undergoes decomposition. Such has

[1] Monro's Elements of Anatomy, i. 579.
[2] Henle, art. Galle, in Encyclop. Wörterb. u. s. w. B. xiii. s. 126, Berlin, 1835.
[3] Expériences sur la Bile des Hommes, &c., in Mém. de l'Académ. de Paris, 1767.
[4] Chimie Organique, p. 451, Paris, 1833.
[5] Annal. der Pharmac., xxvii. cited by Liebig, Animal Chemistry, Webster's edit., p. 305, Cambridge, Mass.
[6] Bulletino Mediche di Bologna, p. 160, Agosto et Settembre, 1836. [7] Op. cit., s. 41.
[8] Hannov. Annal. 1 and 2, 1845, cited in Simon's Animal Chemistry, Sydenham edition, ii. 519, Lond., 1846.

long been the opinion of distinguished chemists, as Berzelius and Mulder, and it is held by one of the most recent analysts, Strecker, who affirms that bile consists essentially of two soda salts, formed of soda and two fatty acids—one of them containing nitrogen and no sulphur; the other a large quantity of sulphur and no nitrogen. Bilin, in other words, is, according to him, a compound substance formed of cholate and sulpho-cholate of soda,—all the other products obtained from it being the results of its decomposition.[1] Messrs. Kirkes and Paget[2] think, that the analysis of Berzelius is the most nearly correct of the many that have been published; but that, after all, its physiology is perhaps more illustrated by its ultimate elementary composition, which shows, that, compared with the organic parts of the blood, it contains a large preponderance of carbon and hydrogen, and a deficiency of nitrogen.

The specific gravity of bile, at 6° centigrade, according to M. Thénard, is 1·026, and John, Schübler and Kapff accord with him. Frerichs found it to be, in one case, 1040; in another, 1·032. Schultz found that of an ox, after feeding, at 15° to be 1·026; of a fasting animal, 1·030. The quantity secreted by a healthy man in the 24 hours has been estimated by Haller and Burdach, and the estimate is adopted by Liebig, at from 17 to 24 ounces; but this is probably higher than the reality. It is difficult, however, to attain the necessary data for a satisfactory evaluation in consequence of its variable degree of concentration.

Hepatic and cystic bile do not appear to differ materially from each other, except in the greater concentration of the different elements in the latter. MM. Leuret and Lassaigne[3] found them to be alike in the dog. M. Orfila,[4] however, affirms, that human hepatic bile does not contain picromel.

When bile is placed in contact with concentrated nitric acid, it first of all assumes a deep green tint, which passes to blue on the addition of a fresh portion of the acid, and to red if we continue to add the acid,—qualities which enable it to be detected in the urine, and in the serum of the blood of the jaundiced.[5] Examined with the microscope, it is seen to contain a few, and but a few, globules of mucus, proceeding, according to M. Mandl,[6] from the muciparous glands of the gall-bladder; lamellæ of cylinder-epithelium swimming in an amorphous liquid, and small yellowish globules. At times, crystals of cholesterin are also observed in it.

It is impracticable to fix upon any average amount of bile secreted in the 24 hours. This must vary according to the amount of food, and

[1] For the analyses of Gunderlach and Strecker, Mulder, and Bensch, see British and Foreign Medico-Chirurgical Review, Jan., 1849, p. 259; also, Carpenter's Principles of Human Physiology, 4th Amer. edit, p. 620; and for those of J. Redtenbacher, Bensch and Strecker, the Report of Scherer in Canstatt and Eisenmann's Jahresbericht über die Fortschritte in der Biologie im Jahre, 1848, s. 78, Erlang., 1849.

[2] Manual of Physiology, Amer. edit., p. 192, Philad., 1849.

[3] Recherches, &c., sur la Digestion, Paris, 1825.

[4] Elém. de Chimie, Paris, 1817.

[5] The Author's Practice of Medicine, 3d edit., i. 669, Philad., 1848.

[6] Manuel d'Anatomie Générale, p. 501, Paris, 1843.

the number of times it is taken, independently of other circumstances. According to Burdach,[1] from the experiments of De Graaf and Keill on dogs, Haller inferred, that 24 ounces are secreted by man in that time. It was not, however, from the experiments of De Graaf and Keill, that Haller drew such inference, but from those of Maurice Van Reverhorst.[2] Liebig estimates the daily discharge at from 17 to 24 ounces.[3] But this estimate is probably much too high. In the experiments of M. Blondlot,[4] twelve and a half drachms on an average were found to be discharged from a fistulous opening in the gall-bladder of a dog; and if the liver of man be supposed—with Haller—to secrete four or five times as much as that of the dog, we should have from six to eight ounces as the average quantity of bile discharged into the intestinal canal of man in the twenty-four hours. The amount contained in the gall-bladder varies. In more than one hundred cases the largest quantity was 111.65 *grammes* (oz. 3·6): the smallest 4·60 *grammes* (dr. 1·18). The average quantity, according to the observations of Von Gorup-Besanez[5] is from 20 to 30 *grammes* (dr. 5·14 to dr. 7·72).

The great uses of the bile have been detailed under the head of digestion. It has been conceived to be a necessary depuratory excretion, separating from the blood matters, that would be injurious if retained. This last idea is probable, and it has been ingeniously urged by MM. Tiedemann and Gmelin,[6] who regard the function of the liver to be supplementary to that of the lungs—in other words, to remove hydro-carbon from the system. The arguments, adduced in favour of their position, are highly specious and ingenious. The resin of the bile, they say, abounds most in herbivorous animals, whose food contains a great disproportion of carbon and hydrogen. The pulmonary and biliary apparatuses are in different tribes of animals, and even in different animals of the same species, in a state of antagonism to each other. The size of the liver, and the quantity of bile are not in proportion to the amount of food and frequency of eating, but inversely proportionate to the size and perfection of the lungs. Thus, in warm-blooded animals, that have large lungs, and live always in the air, the liver, compared with the body, is proportionally less than in those that live partly in water. The liver is still larger in proportion in reptiles, which have lungs with large cells incapable of rapidly decarbonizing the blood,—and in fishes, which decarbonize the blood tardily by the gills; and, above all, in molluscous animals, which effect the same change very slowly, either by gills, or by small imperfectly developed lungs. Again;—the quantity of venous blood, sent through the liver, increases as the pulmonary system becomes less perfect. In the mammalia, and birds, the vena portæ is formed by the veins of the stomach, intestines, spleen, and pancreas; in the tortoise, it receives also the veins of the hind legs, pelvis, tail, and the vena azygos; in serpents, the right renal, and all the intercostal veins; in fishes the renal veins,

[1] Die Physiologie, u. s. w. v. 260, Leipzig, 1835.
[2] Haller, Elementa Physiologiæ, lib. xxiii., sect. 3, § 30, Bern., 1764.
[3] Animal Chemistry, edited by Gregory, Amer. edit., p. 62, Cambridge, 1842.
[4] Essai sur les Fonctions du Foie, p. 61, Paris, 1846.
[5] Op. cit., s. 28.
[6] Die Verdaung nach Versuchen, &c., traduit par Jourdan, Paris, 1827.

and those of the tail and genital organs. Moreover, during the hibernation of certain of the mammalia, when respiration is suspended, and no food taken, the secretion of bile goes on. Another argument is deduced from the physiology of the fœtus, in which the liver is proportionally larger than in the adult, and the bile secreted copiously, as appears from the great increase of the meconium during the latter months of utero-gestation. Their last argument is drawn from pathological facts. In pneumonia and phthisis, the secretion of bile, according to their observations, is increased; in diseases of the heart, the liver is enlarged; and in morbus cæruleus, the organ retains its fœtal proportion. In hot climates, too, where, in consequence of the greater rarefaction of the air, respiration is less perfectly effected than in colder, a vicarious decarbonization of the blood is established by an increased flow of bile. That the separation of bile from the blood is not, however, an indispensable function, notwithstanding the experiments of Schwann, to be mentioned presently, is shown by Dr. Blundell,[1] who gives the cases of two children that lived for four months, apparently well fed and healthy, and on opening their bodies, it was found, that the biliary ducts terminated in a cul-de-sac, and, consequently, not a drop of bile had been discharged into the intestines.

It is proper to remark, that nitrogen is given off likewise in the bile,—being one of the constituents of bilin.

Admitting, then, that the bile is mainly a depuratory secretion, it is probable, that the depuration is effected chiefly on the blood of the portal system. The veins of the stomach and small intestines necessarily absorb much heterogeneous matter, which may be separated by the liver, along with other products which might be injurious if they passed into the mass of blood.

The views of Liebig[2] on this function, as well as on that of the urinary secretion, are ingenious; and, if not true, are at least plausible. Venous blood, before reaching the heart, passes through the liver; arterial blood through the kidney; and both these organs separate from the blood substances that are incapable of serving for the nutrition of the tissues. The compounds which contain the nitrogen of the transformed tissues are collected in the urinary bladder; and, not being inservient to any further use, are expelled from the body. Those, again, which contain the carbon, are collected in the gall-bladder, in the form of a compound of soda—bile—which is miscible with water in every proportion, and passing into the duodenum mixes with the chyme. All those parts of the bile, which, during the digestive process, do not lose their solubility, return, during that process, into the circulation in a state of extreme division. The soda of the bile, and the highly carbonized portions, which are not precipitated by a weak acid, retain the capability of being taken up by the absorbents of the small and large intestines—a capability which has been directly proved by the administration of enemata containing bile,—the whole of the bile having disappeared along with the injected fluid. Liebig affirms,

[1] Stokes, Theory and Practice of Medicine, American Medical Library edition, p. 104, Philad., 1837.

[2] Animal Chemistry, Gregory's edit., p. 57, Cambridge, Mass., 1843.

that the constituents of bile cannot be recognized in the fæces of carnivorous animals; whence he infers that the whole of the bile has been reabsorbed; and—he believes—in order that its hydro-carbon may pass off by the lungs. This can scarcely, however, apply to man; and Liebig admits, that in the herbivora a certain portion of the elements of the bile can be discovered in the fæces. Certainly, a marked difference is observable in them when the biliary ducts are obstructed. As to the precise change effected on the bile in order to fit it for being reabsorbed, Liebig leaves us wholly in the dark. His observations on this matter afford room for interesting reflection; but they can only at present be regarded in the light of suggestions. It would appear, however, from the analyses of different observers, that the fæces of both children and adults contain scarcely any evidences of bile, except in cases in which they are hurried through the canal so that time is not allowed for its absorption.[1] Moreover, the experiments of Schwann[2] seem to show, that it is not a mere excretory fluid, but must be inservient to important purposes in the economy. He removed a portion of the common choledoch duct, and established an external fistulous opening into the gall-bladder, so that the bile, when secreted, might be discharged externally, and not be permitted to enter the intestine. The general result was, that of eighteen dogs operated upon, ten died of the immediate effects of the operation; and of the remaining eight, two recovered, and six died. In the latter, death appeared to result altogether from the removal of the bile. After the third day, they lost weight daily, and had every sign of inanition—as emaciation, muscular debility, uncertain gait, falling off of the hair, &c. They lived from seven to sixty-four days after the operation, and the longer they survived, the more marked were the signs of inanition. Licking the bile, as it flowed from the opening, and swallowing it, had no influence on the results. In the two dogs that recovered, the importance of the bile was equally shown; for it was found, when they were killed, that the passage of the bile into the intestine had been restored, and the period of its restoration was distinctly shown by their weight—which had previously been regularly and progressively decreasing—becoming augmented, and continuing to augment until it amounted to what it was before the operation; and likewise by the fistulous opening into the gall-bladder healing, and the discharge of bile ceasing. These experiments do not, however, lead to any exact inference as to the mode in which the bile exerts its important agency. It is proper, however, to add, that Schwann's experiments, when repeated with some modifications by M. Blondlot,[3] led to very different results. In the first of these, an external fistulous opening was made into the gall-bladder of a dog, and the ductus communis choledochus having been tied in two places it was divided between the ligatures. At first the animal appeared distressed, but in a few hours it recovered. The bile continued to flow from the external opening, and was constantly licked

[1] Pettenkofer, cited by Von Gorup-Besanez, Untersuchungen über Galle, s. 51, Erlangen, 1846.
[2] Müller's Archiv., Heft ii. 1844.
[3] Essai sur les Fonctions du Foie et de ses Annexes, Paris, 1846.

off. On the 15th day, the wound had healed with the exception of the small aperture through which the bile flowed. The dog was then muzzled to prevent his licking it; after which the fæces became discoloured and hard. At this time he had become much emaciated although he had eaten heartily; but he now began to regain his flesh, and at the end of three months was perfectly well and active, and so continued. Another animal, which was experimented on in the same way, and presented the same phenomena, was killed at the end of forty days, when it was found that the ductus communis choledochus had become completely obliterated. From these experiments—too few perhaps to establish positive conclusions—M. Blondlot inferred, that the bile plays no important part in the process of digestion, and that it is essentially, and wholly, an excrementitious fluid.

Of late, it has been affirmed by M. Bernard[1] on the strength of experiments instituted by him, that a regular function of the liver is the formation of sugar. The fact of the conversion of amylaceous into saccharine matter by the contact of blood, saliva, &c., has been elsewhere referred to;[2] but from his researches, it would follow, that the liver alone has the power of producing sugar without starch, and that such production is connected with the integrity of the pueumogastric nerves. We are told by M. Magendie,[3] that M. Bernard, after several experiments, discovered that if the floor of the fourth ventricle was pierced within a very circumscribed space, in less than half an hour, a very considerable quantity of sugar—diabetic sugar—was found in the blood and urine, without the regimen of the animal having undergone any change whatever. This fact attracted M. Bernard's attention to the condition of the floor of the fourth ventricle in diabetic patients, and in one case, on dissection, two dark spots were observed on the part, which must be penetrated to produce the sugar. Increased saccharine formation was likewise caused by pricking or gently galvanizing the eighth pair in the neck, whilst it was suspended by dividing both pneumogastrics. As the sugar is formed in the liver, it is conveyed away by the veins proceeding from the organ, and has been detected by M. Bernard in the hepatic veins, vena cava superior, and right cavities of the heart; whilst in other parts of the body the blood contains none or very feeble traces of it, except after the digestion of amylaceous substances, when a notable quantity may be found in all the veins. As the saccharine matter, produced by the liver under the circumstances mentioned, is not met with in the pulmonary veins, M. Magendie infers, that it must have undergone destruction in the lungs; and he thinks it not impossible, that from such destruction the carbonic acid of respiration may result, as has been presumed by many physiologists to be the case with every form of sugar. All sugars, however, do not appear to be affected in the same manner. If, according to the same observer, we inject into the blood

[1] Archives Générales, Nov. 1848; see, also, Ranking's Half-Yearly Abstract of the Medical Sciences, ix. 215, Jan. to June, 1849.

[2] Vol. i. p. 566.

[3] Report of M. Magendie's Lectures at the College of France, in Union Médicale, Nos. 72, 75 and 79. The report is translated in British and Foreign Medico-Chirurgical Review, p. 545, Oct., 1849.

a solution of cane sugar, mannite, or the sugar of milk, the whole of it will be found in the urine; but if we inject glucose or grape sugar, except in large quantity, none of it can be detected in that fluid. But if an animal be fed on the first mentioned varieties of sugar, they are not found in the urine; because, according to M. Magendie, digestion has transformed them into glucose, and this has become decomposed in the lungs. The following table is given by him to exhibit the quantity of the different kinds of sugar that must be injected into the jugular vein, in order that they may be detected in the urine. It shows—as he has remarked—that "the natural sugar of the economy is destroyed in the act of respiration with far greater facility than that proceeding from alimentary substances:—

Cane sugar,	0·05
Mannite,	0·05
Sugar of milk,	0·25
Glucose,	2·50
Sugar of the liver,	12·00"

These experiments are curious, and demand careful repetition. The results—it has been seen—are admitted by M. Magendie; but so much evil has flowed from the too hasty reception of the phenomena presented by experiments on living animals, that the author waits for further developements.

If the excretion of the bile be prevented from any cause, we know that derangement of health is induced; but it is probable, that its agency in the production of disease is much overrated; and that, as M. Broussais has suggested, the source of many of the affections termed *bilious* is in the mucous membrane lining the stomach and intestines; which, owing to the heterogeneous matters constantly brought into contact with it, must be peculiarly liable to be morbidly affected. When irritation exists there, we can understand how the secretion from the liver may be consecutively modified,—the excitement spreading directly along the biliary ducts to the secretory organ.

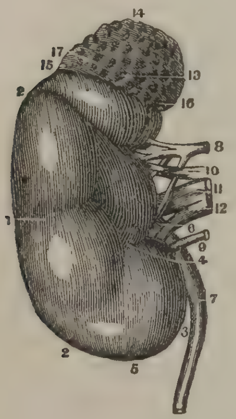
6. *The Urinary Secretion.*

This is the most extensive secretion accomplished by any of the glandular structures of the body, and is essentially depuratory; its suppression giving rise to formidable evils. The apparatus consists of the *kidneys*, which secrete the fluid; the *ureters*, which convey the urine to the bladder; the *bladder* itself, which serves as a reservoir for the urine; and the *urethra*, which conveys the urine externally. These require a distinct consideration.

The *kidneys* are two glands situate in the abdomen; one on each side of the spine, in the posterior part of the lumbar region. They are without the cavity of the peritoneum, which covers them at the anterior part only; and are situate in the midst of a considerable mass of adipous areolar tissue. The right kidney is nearly an inch lower than the left, owing to the presence of the thick posterior margin of the right lobe of the liver. Occasionally, there is but one kidney; at other times, three have been met with. They have the form of the *haricot* or *kidney-bean*, which has indeed, been called

after them; and are situate vertically,—the fissure being turned inwards. If we compare them with the liver, their size is by no means in proportion to the extensive secretion effected by them. Their united weight does not amount to more than six or eight ounces. Of 65 male kidneys, weighed by Dr. John Reid,[1] the average was found to be 5 oz. 7 dr. for the right kidney; 5 oz. 11½ dr. for the left. Of 28 female kidneys, the right weighed 4 oz. 13 dr.; the left, 5 oz. 2 dr. The left kidney generally weighs more than the right at all ages. The kidneys of the new-born child, although absolutely much lighter than those of the adult, are yet, according to M. Huschke,[2] in proportion to the whole body much heavier; inasmuch as their weight is to that of the

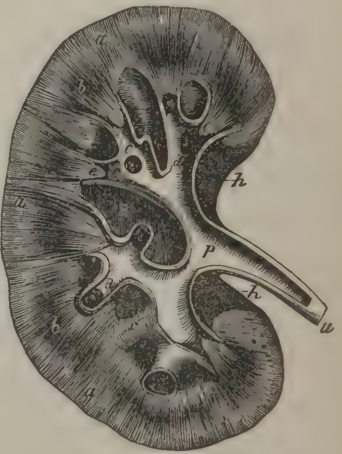
Fig. 350.



Right Kidney with its Renal Capsule.

1. Anterior face of Kidney. 2. External or convex edge. 3. Its internal edge. 4. Hilum renale. 5. Inferior extremity of kidney. 6. Pelvis of ureter. 7. Ureter. 8, 9, Superior and inferior branches of emulgent artery. 10, 11, 12. Three branches of the emulgent vein. 13. Anterior face of renal capsule. 14. Its superior edge. 15. Its external edge. 16. Its internal extremity. 17. Fissure on the anterior face of the capsule.

Fig. 351.



Plan of a Longitudinal Section of the Kidney and Upper Part of the Ureter, through the Hilus, copied from an enlarged model.

a, a, a. The cortical substance. *b, b.* Broad part of two of the pyramids of Malpighi. *e, e.* Section of the narrow part or apex of two of these pyramids, lying within the divisions of the ureter marked *c, e.* *d, d.* Summits of the pyramids, called papillæ, projecting into and surrounded by the divisions of the ureter. *c, c.* Divisions of the ureter, called the calices or infundibula, laid open. *c'.* A calix or infundibulum unopened. *p.* Enlarged upper end of ureter, named the pelvis of the kidney. *s.* Central cavity or sinus of the kidney.

whole body of the infant, as 1 to 82–100; in the adult as 1 to 225. They, therefore, do not grow uniformly with the body, although the secretion of urine becomes more energetic after birth.

The kidneys are hard, solid bodies, of a brown colour. The sanguiferous vessels, which convey and return the blood to them, as well as the excretory duct, communicate with them at the fissure.

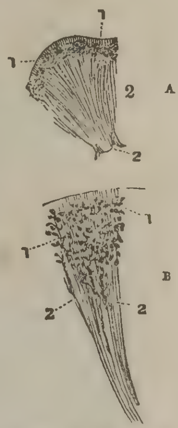
The anatomical constituents of these organs are;—1. The *renal artery*, which arises from the abdominal aorta at a right angle, and,

[1] Lond. and Edinb. Monthly Journal of Med. Sciences, April, 1843, p. 323.
[2] Encyclop. Anatom., traduit par Jourdan, v. 321, Paris, 1845.

after a short course, enters the kidney, ramifying in its substance. 2. The *excretory ducts*, which arise from every part of the tissue, in which the ramifications of the renal artery terminate. They end in the *pelvis* of the kidney. (Fig. 351.) 3. The *renal veins*, which receive the superfluous blood, after the urine has been separated from it, and terminate in the *renal* or *emulgent vein*, which issues at the fissure, and opens into the abdominal vena cava. 4. Lymphatic vessels, arranged in two planes —a superficial and a deap-seated, which terminate in the lumbar glands. 5. *Nerves*, which proceed from the semilunar ganglion, solar plexus, &c., and surround the renal artery as with a network, following it in all its ramifications. 6. Areolar membrane, which, as in every other organ, binds the parts together. These anatomical elements, by their union, constitute the organ as we find it.

When the kidney is divided longitudinally, it is seen to consist of two substances, which differ in their situation, colour, consistence, and texture. One of these, and the more external, is called the *cortical glandular* or *vascular substance.* It forms the whole circumference of the kidney; is about two lines in thickness; of less consistence than the other; of a pale red colour; and receives almost entirely the ramifications of the renal artery. The other and innermost is the *tubular*, *medullary*, *uriniferous*, *conoidal* or *radiated substance.* It is more dense than the other; less red; and seems to be formed of numerous minute tubes, which unite in conical bundles of unequal size—*pyramids of Malpighi*—the base of which is turned towards the cortical portion, —the apices forming the *papillæ* or *mammillary processes*, and facing the pelvis of the kidney. The papillæ vary in number from five to eighteen; are of a florid colour; and upon their points or apices are terminations of uriniferous tubes large enough to be distinguished by the naked eye. Around the root of each papilla, a membranous tube arises called *calix* or *infundibulum:* this receives the urine from the papilla, and conveys it into the *pelvis* of the kidney, which may be regarded as the commencement of the ureter.

Fig. 352.

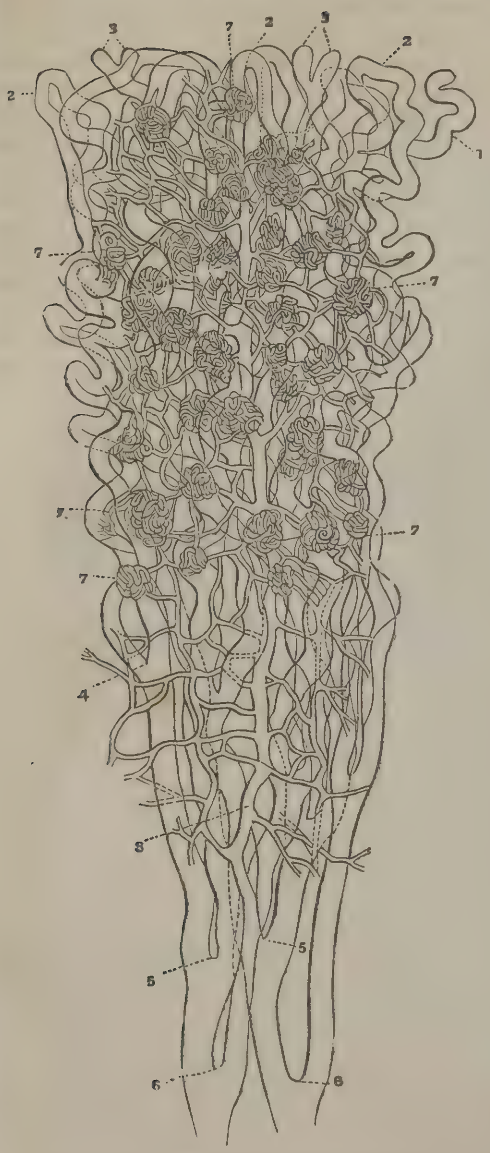


Portion of Kidney of New-born Infant.

A. Natural size. B. A small portion of A magnified. 1, 1. Corpora Malpighiana. 2. Tubuli uriniferi. (Wagner.)

The cortical part of the kidney is the most vascular; and the plexus formed by the tubuli uriniferi appears to come there in closest relation with that formed by the renal capillaries. In the illustration (Fig. 352) of the two portions as they appear in the new-born infant, A exhibits them of the natural size:—1, 1, *Corpora Malpighiana* or Malpighian bodies, appearing as points in the cortical substance. 2. One of the papillæ. These Malpighian bodies are scattered through the plexus formed by the bloodvessels and uriniferous tubes. Each one, when examined by a high magnifying power, is found to consist of a convoluted mass of minute bloodvessels. In them—it was at one time supposed—the uriniferous tubes originate; but the examinations of Müller and Huschke have seemed to show, that they are only capable of injection from

Fig. 353.



Small Portion of Kidney magnified 60 diameters.

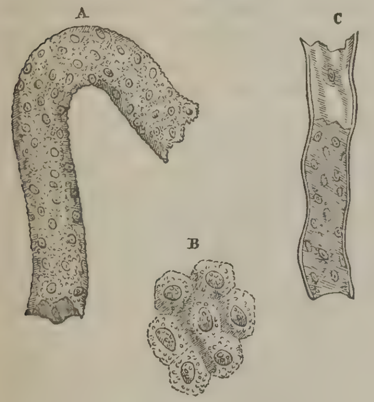
1. Cæcal extremity of a tubulus. 2, 2. Loops of tubuli. 3, 3. Bifurcated tubuli. 4, 5, 6. Tubuli converging towards the papillæ. 7, 7, 7. Corpora Malpighiana. 8. Arterial trunk.

the arteries or veins. They are found in the kidneys of most, if not all, of the vertebrata. In the cortical substance, according to Wagner,[1] the tubuli can be traced, although with difficulty, winding among the vascular plexuses or skeins, mostly looped towards the margin of the organ, and running into one another, or having blind or cæcal extremities; more rarely enlarged and club-shaped as in Fig. 48, and occasionally cleft (Fig. 353). The entire cortical substance, according to Wagner, consists of convolutions of the uriniferous tubes, which present a nearly uniform diameter, on an average, from about the 60th to the 50th of a line. Professor Goodsir,[2] however, without denying the existence of occasional blind extremities of the tubuli uriniferi — the result probably, he thinks, of arrested developement —states, that he has never seen the ducts terminate in this way. He has described a fibro-cellular framework, which, pervading every part of the gland, and particularly its cortical portion, performs the same office in the kidney, which the capsule of Glisson does in the

[1] Elements of Physiology, by R. Willis, § 193, Lond., 1842.
[2] Lond. and Edinb. Monthly Journ. of Med. Science, May, 1842.

liver,—being a basis of support to the delicate structure of the gland, conducting the bloodvessels through the organ, and constituting small chambers in the cortical portion, in each of which a single ultimate coil or loop of the uriniferous ducts is lodged. Mr. Goodsir believes, that the urine is formed at first within the epithelium cells of the ducts, and that these burst, dissolve, and throw out their contents, and are succeeded by others, which perform the same functions. The urine of man has not been detected by Mr. Goodsir within the cells, that line the ducts, but he has submitted to the Royal Society of Edinburgh a memoir, already referred to, in which he has endeavoured to show,

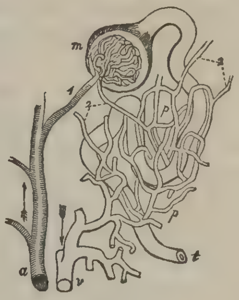
Fig. 354.



Tubuli Uriniferi. (Baly.)

A. Portion of a secreting canal from the cortical substance of the kidney. B. The epithelium or gland-cells, more highly magnified (700 times). C. Portion of a canal from the medullary substance of the kidney. At one part the basement membrane has no epithelium liningit.

Fig. 355.



Plan of the Renal Circulation. (Bowman.)

a. A branch of the renal artery giving off several Malpighian twigs. 1. An afferent twig to the capillary tuft contained in the Malpighian body, *m*; from the Malpighian body the uriniferous tube is seen taking its tortuous course to *t*. 2, 2. Efferent veins: that which proceeds from the Malpighian body is seen to be smaller than the corresponding artery. *p*, *p*. The capillary venous plexus, ramifying upon the uriniferous tube. This plexus receives its blood from the efferent veins, 2, 2, and transmits it to the branch of the renal vein, *v*.

that urine, bile, and milk, as well as the other more important secretions in the lower animals, are formed within the nucleated cells of the ducts themselves; and he is of opinion, that the urine of man is poured at first into the cavities of the nucleated cells of the human kidney.

Mr. Bowman[1] has affirmed, that the kidney is furnished with a true *portal system*, and that the urine, like the bile, is secreted—in part at least—from blood, traversing at the time a second set of capillaries. According to him, each of the exceedingly tortuous and convoluted urinary conduits terminates, at its final extremity, by a contracted neck, which leads into a little chamber or cyst,—*capsule of Malpighi*—in which is contained the true *glandule*, *corpuscle* or *glomerule* of Malpighi. This consists of a tuft or coil of capillary bloodvessels, totally naked, which originates in one of the ultimate branches of the

[1] Proceedings of the Royal Society, No. lii., Feb. 3, 1842; and Philos. Transactions, Pt. 1, p. 57, Lond., 1842.

renal artery, and terminates in an efferent vessel. Several of these latter form, by their anastomosing ramifications, the plexus that surrounds each urinary conduit and tubule; the urinary conduits being lined by thick epithelium, and their necks furnished with vibratile cilia.[1] All the blood of the renal artery, according to Mr. Bowman,—with the exception of a small quantity distributed to the capsule, surrounding fat, and the coats of the larger vessels,—enters the capillary tufts of the corpora Malpighiana; thence passes into the capillary plexus surrounding the uriniferous tubes, and finally leaves the organ through the branches of the renal vein. According to this view, there are in the kidney two perfectly distinct systems of capillary vessels; the *first*, that inserted into the dilated extremities of the uriniferous tubes, and in immediate connexion with the arteries—the Malpighian bodies:—the *second*, that enveloping the convolutions of the tubes, and communicating directly with the veins. The efferent vessels of the Malpighian bodies, that carry the blood between these two systems, are termed by Mr. Bowman the *portal system of the kidney*. The views of Mr. Bowman have been embraced by many histologists,[2] whilst every one of them has been strenuously denied by others. In regard to the precise arrangement of the Malpighian bodies, histologists are by no means in accordance. Gerlach for example, found, that instead of the flask-like dilatation being placed, as maintained by Mr. Bowman, at the extremity of a uriniferous tube, it may be, and is formed by off-sets from the sides of the tube; so that the capsules may be either terminal or lateral.[3]

In the quadruped, each kidney is made up of numerous lobes, which are more or less intimately united according to the species. In birds, the kidney consists of a double row of distinct, but connected, glandular bodies, placed on both sides the lumbar vertebræ.

The *ureter* is a membranous duct, which extends from the kidney to the bladder. It is about the size of a goosequill; descends through the lumbar region; dips into the pelvis by crossing in front of the primitive iliac vessels and the internal iliac; crosses the vas deferens at the back of the bladder; and, penetrating that viscus obliquely, terminates by an orifice ten or twelve lines behind that of the neck of the bladder. At first, it penetrates two of the coats only of that viscus; running for the space of an inch between the mucous and muscular, and then entering the cavity. The ureters have two coats. The outermost is a dense fibrous membrane; the innermost a thin mucous layer, continuous at its lower extremity with the inner coat of the bladder; and, at the upper end, supposed by some to be reflected over the papillæ, and even to pass for some distance into the tubuli uriniferi.

The *bladder* is a musculo-membranous sac, situate in the pelvis; anterior to the rectum, and behind the pubes. Its superior end is called

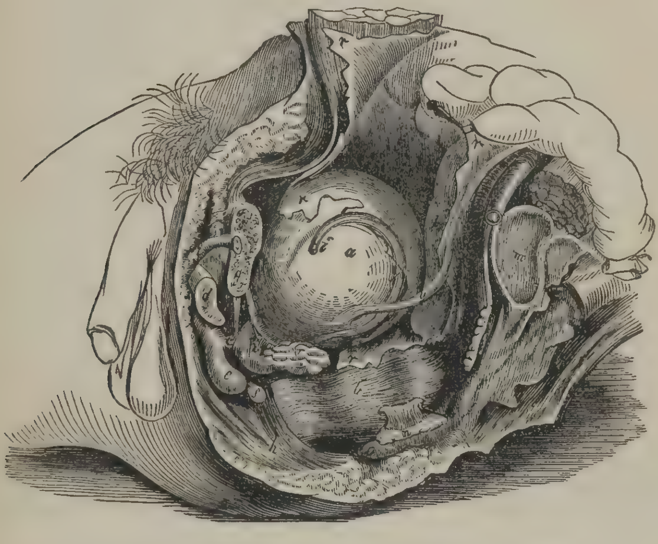
[1] See Fig. 48, vol. i. p. 132.

[2] See on the whole subject Dr. Geo. Johnson, in the article Ren, Cyclopædia of Anatomy and Physiology, Pt. xxxii. p. 244, Lond., August. 1848; and Gerlach, Handbuch der Gewebelehre, s. 301, Mainz, 1849; and A. H. Hassall, The Microscopic Anatomy of the Human Body, Pt. xiii. p. 427, Lond., 1848.

[3] Gerlach, op. cit., and in Müller's Archiv. für Anatomie, s. 378, 1845; and Ibid., s. 102, 1848.

upper fundus; and the lower end, *inferior fundus* or *bas-fond;* the *body* being between the two. The part where it joins the urethra is the *neck.* The shape and situation of the organ are influenced by age and sex. In very young infants, it is cylindroid, and rises almost wholly into the abdomen. In the adult female, who has borne many children, it is nearly spherical; has its greatest diameter transverse, and is more capacious than in the male. Like the other hollow viscera, the bladder consists of several coats. 1. The *peritoneal,* which covers only the fundus and back part. Towards the lower portion the organ is invested by areolar membrane, which takes the place of the peritoneal coat of the fundus. This tissue is very loose, and permits the distension and contraction of the bladder. 2. The *muscular coat* is very strong; so much so, that it has been classed amongst the distinct muscles, under the name *detrusor urinæ.* The fibres are pale, unstriped, and pass in

Fig. 356.



Lateral View of the Viscera of the Male Pelvis. (Quain.)

a. Bladder. *b. b'.* Rectum. *c.* Membranous portion of the urethra. *d.* Section of left crus, or corpus cavernosum. *e.* Bulbous extremity of corpus spongiosum or bulb of urethra. *f.* Cowper's gland. *g.* Section of body of pubes. *h.* Sphincter ani muscle. *i.* Part of left vas deferens. *m.* Articular surface of sacrum. *n.* Spine of left ischium sawn off. *o.* Coccyx. *p.* Prostate gland. *r, r.* Peritoneum. *r'.* Cul-de-sac between bladder and rectum. *u.* Left ureter. *v.* Left vesicula seminalis.

various directions. Towards the lower part of the bladder, they are particularly strong; arranged in fasciculi, and form a kind of network of muscles enclosing the bladder. In cases of stricture of the urethra, where much effort is necessary to expel the urine, these fasciculi acquire considerable thickness and strength. 3. The *mucous* or *villous coat* is the lining membrane, which is continuous with that of the ureters and urethra, and is generally rugous in consequence of its being more extensive than the muscular coat without. It is furnished with numerous follicles, which secrete a fluid to lubricate it. Towards the neck of the

organ, it is thin and white, although reddish in the rest of its extent. A fourth coat, called the *cellular*, has been reckoned by most anatomists, but it is nothing more than areolar tissue uniting the mucous and muscular coats. The part of the internal surface of the bladder, situate immediately behind and below its neck, and occupying the space between it and the orifices of the ureters, is called *vesicle triangle*, *trigonus Lieutaudi* or *trigone vésical*. The anterior angle of the triangle looks into the orifice of the urethra, and is generally so prominent, that it has obtained the name *uvula vesicæ*. It is merely a projection of the mucous membrane, dependent upon the subjacent third lobe of the prostate gland, which, in old people, is frequently enlarged, and occasions difficulty in passing the catheter. The neck of the bladder penetrates the prostate; but, at its commencement, it is surrounded by loose areolar tissue, containing a very large and abundant plexus of veins. The internal layer of muscular fibres is here transverse; and they cross and intermix with each other in different directions, forming a close, compact tissue, which has the effect of a particular apparatus for retaining the urine, and has been called the *sphincter*. Anatomists have not usually esteemed this structure to be distinct from the muscular coat at large; but Sir Charles Bell[1] asserts, that if we begin the dissection by taking off the inner membrane of the bladder from around the orifice of the urethra, a set of fibres will be discovered on the lower half of the orifice, which, being carefully dissected, will be found to run in a semicircular form around the urethra. These fibres make a band of about half an inch in breadth, particularly strong on the lower part of the opening; and having ascended a little above the orifice on each side, they dispose of a portion of their fibres in the substance of the bladder. A smaller and somewhat weaker set of fibres will be seen to complete their course, surrounding the orifice on the upper part. The arteries of the bladder proceed from various sources, but chiefly from the umbilical and common pudic. The veins return the blood into the internal iliacs. They form a plexus of considerable size upon each side of the bladder, particularly about its neck. The lymphatics accompany the principal veins of the bladder, and, at the under part and sides, pass into the iliac glands. The nerves are from the great sympathetic and sacral.

The *urethra* is the excretory duct of the bladder. It extends, in the male, from the neck of the bladder to the extremity of the glans; and is from seven to ten inches in length. In the female it is much shorter. The male urethra, in the state of flaccidity of the penis, has several curvatures; but is straight, or nearly so, if the penis be drawn forwards and upwards, and the rectum be empty. The first portion of this canal, which traverses the prostate gland, is called the *prostatic portion*. Into it open,—on each side of a caruncle, called *verumontanum*, *caput gallinaginis* or *crista urethralis*,—the two ejaculatory ducts, those of the prostate, and a little lower, the orifice of Cowper's glands. Between the prostate and the bulb is the *membranous part* of the urethra, which is eight or ten lines long. The remainder of the canal is called *corpus*

[1] Anatomy and Physiol., 5th Amer. edit. by Dr. Godman, ii. 375, New York, 1829.

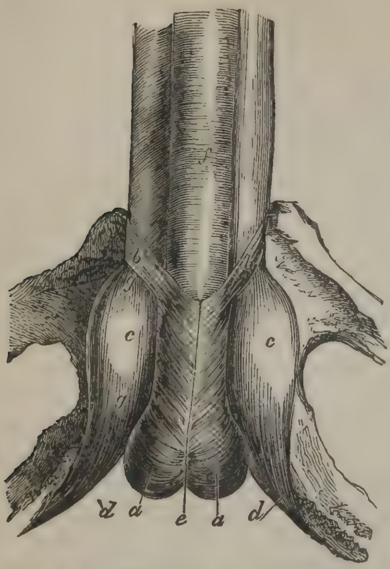
spongiosum or *spongy portion*, because surrounded by an erectile spongy tissue. It is situate beneath the corpora cavernosa, and passes forward to terminate in the *glans*, the structure of which will be considered under Generation. At the commencement of this portion of the urethra is the *bulb*, the structure of which resembles that of the corpora cavernosa of the penis—to be described hereafter. The dimensions of the canal are various. At the neck of the bladder it is considerable: behind the caput gallinaginis it contracts, and immediately enlarges in the forepart of the prostate. The membranous portion is narrower; and in the bulb the channel enlarges. In the body of the penis, it diminishes successively, till near the glans, when it is so much increased in size as to have acquired the name *fossa navicularis*. At the apex of the glans it terminates by a short vertical slit. Mr. Shaw[1] has described a set of vessels, immediately on the outside of the internal membrane of the urethra, which, when empty, are very similar in appearance to muscular fibres. These vessels, he remarks, form an internal spongy body, which passes down to the membranous part of the urethra, and forms even a small bulb there. Dr. Horner,[2] however, says, that this appeared to him to be rather the cellular membrane connecting the canal of the urethra with the corpus spongiosum. The whole of the urethra is lined by a very vascular and sensible mucous membrane, which is continuous with the inner coat of the bladder. It has, apparently, a certain degree of contractility; and therefore, by some anatomists, is conceived to possess muscular fibres. Sir Everard Home, from the results of his microscopical observations, is disposed to be of this opinion. This is, however, so contrary to analogy, that it is probable the fibres may be seated in the tissue surrounding it. The membrane contains numerous follicles, and several lacunæ, one or two of which, near the extremity of the penis, are so large as occasionally to obstruct the catheter, and convey the impression that a stricture exists.

The prostate and glands of Cowper, being more concerned in generation, will be described hereafter.

There are certain muscles of the perineum, that are engaged in the expulsion of the urine from the urethra; and some of them in defecation, and the evacuation of sperm likewise;—as the *acceleratores urinæ* or *bulbo-urethrales*, which propel the urine or semen forward;[3] the *transversus perinei* or *ischio-perinealis*, which dilates the bulb for the reception of the urine or sperm; the *sphincter ani*, which draws down the bulb, and aids in their ejection; and the *levator ani*, which surrounds the extremity of the rectum, the neck of the bladder, the membranous portion of the urethra, the prostate gland, and a part of the vesiculæ seminales, and assists in the evacuation of the bladder, vesiculæ seminales, and prostate. A part of the levator, which arises from the pubis and assists in inclosing the prostate, is called by Sömmering *compressor prostatæ*. Between the membranous part of the urethra, and that portion of the levator

[1] Manual of Anatomy, ii. 118, Lond., 1822.
[2] Lessons in Practical Anatomy, 3d edit., p. 272, Philad., 1836.
[3] For Dr. Horner's views on the origin of the acceleratores urinæ, see his Special Anatomy and Histology, 7th edit., Philad., 1848.

Fig. 357.



Part of the Ossa Pubis and Ischia, with the Root of the Penis attached. (Kobelt.)

a, a. Accelerator urinæ muscle, embracing the bulb of the urethra, which is slightly notched in the middle line, *e*, behind. *b, b.* Anterior slips of the accelerator muscle, which pass round to the dorsum of the penis. *c, c.* Crura of the penis. *d, d.* Erectores penis muscles lying on the crura. *f.* The corpus spongiosum urethræ. *g*, to *g*. Enlargement of the crus, named the bulb of the corpus cavernosum.

ani, which arises from the inner side of the symphysis pubis, a reddish, areolar, and very vascular substance exists, which closely surrounds the canal, has been described by Mr. Wilson[1] under the name *compressor urethræ*, and is termed, by some of the French anatomists, *muscle de Wilson*. By many, however, it is considered to be a part of the levator ani. M. Amussat asserts, that the membranous part of the urethra is formed externally of muscular fibres, which are susceptible of energetic contraction; and M. Magendie[2] confirms his assertion.

With regard to the *urinary organs* of the *female*:—the kidneys and ureters have the same situation and structure as those of the male. The bladder, also, holds the same place behind the pubis; but rises higher when distended. It is proportionally larger than that of the male, and is broader from side to side, thus permitting the greater retention to which females are often necessitated. The urethra is much shorter, being only about an inch and a half or two inches long; and it is straighter than in the male, having only a slight curve downwards between its extremities, and passing almost horizontally under the symphysis pubis. It has no prostate gland, but is furnished, as in the male, with follicles and lacunæ, which provide a mucus to lubricate it.

In birds, in general, and in many reptiles and fishes, the urine, prior to expulsion, is mixed with the excrement in the cloaca. Nothing analogous to the urinary organs has been detected in the lowest classes of animals, although in the dung of the caterpillars of certain insects, traces of urea have been met with.

The urine is formed from the blood in the kidneys; and it has, until recently, been the universal belief, that it is secreted from arterial blood; Mr. Bowman, however, in accordance with views on the minute anatomy of the kidney already given, has attempted to show, that it is separated from venous blood. His main conclusions are as follows:—*First.* The epithelium lining the tubes is the proper organ that secretes the characteristic products of urine from the blood; and

[1] Lectures on the Structure and Physiology of the Urinary and Genital Organs, Lond., 1821.
[2] Précis, &c., ii. 472.

it does this by first assimilating them into its own substance, and afterwards pouring them upon its free surface. *Secondly*. These proper urinous products require for their solution a large quantity of water. *Thirdly*. This water is furnished by the Malpighian tufts of capillaries, placed at the extremity of the uriniferous tubes; and *Fourthly*. A farther use of the Malpighian bodies seems to be that of sharing in regulating the amount of water in the body. He thus makes a striking analogy between the liver and the kidney both in structure and function; and expresses his belief,—*first*, that diuretic medicines act specially on the Malpighian bodies, and that many substances, particularly salts, which, when taken into the system, have a tendency to pass off by the kidneys with rapidity, in reality escape through the Malpighian bodies: *secondly*, that certain morbid products occasionally found in the urine, such as sugar, albumen, and the red particles of the blood, in all probability, pass off through this bare system of capillaries. The discovery, however, by Gerlach,[1] and others, that the proper Malpighian capsule is invariably lined by innumerable granular cells, naturally suggested, that the Malpighian body is destined for some action of elaboration, and that it is as much concerned in the proper urinary secretion as the uriniferous tubes; and on these grounds Mr. Hassall expresses the belief, that urine is formed in every part of the tubular and Malpighian surface of the kidney; and he thus dissents from the opinion of Mr. Bowman, that the Malpighian body is an apparatus destined for the simple separation of the watery parts of the urine; whilst he agrees with him, that the greater portion of the more watery parts proceed from the Malpighian bodies;—which is probable. It is not so easy to accord with him, that the last action is not "effected by an act of simple separation but by one of secretion." A simple physical act of endosmose—it need scarcely be said—is alone needed in the case of a tenuous fluid; and cell agency is only required where an action of elaboration has to be exerted.

According to M. Raspail,[2] the urine is a kind of *caput mortuum*, ejected into the urinary bladder by the kidneys. They separate carbon and nitrogen in the form of cyanogen, which unites with oxygen to produce cyanic acid; and this combines with ammonia—itself a compound of nitrogen and hydrogen—to form urea, which is the characteristic element of the urinary secretion. They separate also, and excrete superfluous fluid from the body. The proofs of such separation are easy and satisfactory; but with regard to the mode in which the operation is effected, we are in the same darkness that hangs over glandular secretions in general. The transformation doubtless occurs mainly in the cortical part of the organ, and essentially in the same manner as other secretions are formed from the blood;—the action of elaboration taking place through the agency of cells, which burst and discharge the proper urinary matter into the uriniferous tubes.

The urinary secretion takes place continuously. If a catheter be left in the bladder, the urine drops constantly; and in cases of *exstrophia* of that organ—a faulty conformation, in which a red mucous surface,

[1] Op. cit.

[2] Chimie Organique, p. 505, Paris, 1833.

formed by the inner coat of the bladder, is seen in the hypogastric region on which two prominences are visible, corresponding to the openings of the ureters, the urine is observed to be constantly oozing from the openings.[1] A case of the kind the author has had repeated opportunities of exhibiting to his class in the Jefferson Medical College. After the secretion has been effected in the cortical substance, it flows through the tubular, and issues *guttatim* through the apices of the papillæ into the pelvis of the kidney, whence it proceeds along the ureter to the bladder. If the uriniferous cones be slightly compressed, urine issues in greater quantity; but, instead of being limpid, as when it flows naturally, it is thick and troubled. Hence a conclusion has been drawn, that it is really filtered through the hollow fibres of the medullary or tubular portion. If this were the case, what must become of the separated thick portion? Ought not the tubes to become clogged up with it? And is it not more probable, that compression, in this case, forces out with the urine some of the blood that is concerned in the nutrition of the organ? The fresh secretion constantly taking place in the kidney causes the urine to flow along the tubuli uriniferi to the pelvis of the organ, whence, in the erect attitude, it proceeds along the ureter, by virtue of its gravity: the fresh fluid, too, continually secreted from the kidney, pushes on that before it: moreover, there is not improbably some degree of contractile action exerted by the ureters themselves; although, as in the case of action of the excretory ducts in general, such a power has been denied them. These, with the cilia of the lining membrane,[2] are the chief causes of the progression of the urine into the bladder, which is aided by the pressure of the abdominal contents and muscles; and, it is supposed, by the pulsation of the renal and iliac arteries; but the agency of these must be trivial.

The orifices of the ureters form the posterior angles of the *trigone vésical*, and are contracted somewhat below the size of the ducts themselves. They are said by Sir Charles Bell[3] to be furnished with a small fasciculus of muscular fibres, which runs backwards from the orifice of the urethra, immediately behind the lateral margins of the triangle; and, when it contracts, stretches the orifice of the ureter so as to permit the urine to enter the bladder with facility. As the urine passes in, it gradually distends the organ until the quantity has attained a certain amount. It cannot reflow by the ureters, on account of the smallness of their orifices and their obliquity; and as the bladder becomes filled,—owing to the duct passing for some distance between the muscular and mucous coats,—the sides are pressed against each other, so that the cavity is obliterated. As, however, the ureters have a tendency to lose this obliquity of insertion, in proportion as the bladder is emptied, the two bands of muscular fibres, which run from the back of the prostate gland to the orifices of the ureters, not only assist in emptying the bladder, but, at the same time, pull down the orifices of the ureters, and thus tend to preserve the obliquity. Moreover, when we are in

[1] A case of this kind is detailed by the author, in Amer. Med. Intelligencer, i. 137; and another, by Dr. Pancoast, ibid., p. 147, Philad., 1838.

[2] On the Ciliary Motion of the Tubes, see Dr. George Johnson, art. Ren, supra cit., p. 253.

[3] Anatomy and Physiology, 5th American edition, by Godman, ii. 381, New York, 1827.

the erect attitude, the urine would have to enter the ureters against gravity. These obstacles are so effective, that if an injection be thrown forcibly and copiously through the urethra into the bladder, it does not enter the ureters. On the other hand, equally powerful impediments exist to its being discharged through the urethra. The inferior fundus of the bladder is situate lower than the neck; and the sphincter presents a degree of resistance, which requires the bladder to contract forcibly on its contents, aided by the abdominal muscles to overcome it. Magendie[1] considers the contraction of the levatores ani to be the most efficient cause of the retention of the urine; the fibres which pass around the urethra pressing its sides against each other, and thus closing it. In a case of exstrophy of the bladder, Mr. Erichsen[2] had an opportunity of marking several interesting phenomena connected with the excretion of urine. The orifice of each ureter in the bladder appeared, when closed, as a small irregularly oval depression, about a line in diameter, situate on a conical papilla of the mucous membrane. A probe might be passed up the ureters for several inches without any sensible inconvenience being sustained. In regard to the phenomena attending the passage of the urine from the ureters into the bladder, it appeared, that in the first place a drop collected within the papillary termination of the ureter, which became somewhat distended; the orifice of the canal then opened to an extent of from two to three lines in diameter, and, as soon as it had allowed the drop of urine to pass, it contracted with a sphincter-like action. The distension of the lower end of the ureter, before the drop of urine escaped, was very distinct; and the relaxation of the orifice of the canal had the appearance of being occasioned by the accumulation of the drop of fluid that collected above it. The closure of the vesical termination of the ureter, after the escape of the drop of urine, was accompanied by a slight retraction of the papillary bulging of the mucous membrane on which it terminated, and the whole process resembled an ordinary sphincter action. The two ureters did not open at the same time, but with an irregularly alternating action. During the periods of fasting, they opened on an average about three times in a minute; consequently, the quantity of urine discharged from both might be estimated at about three large drops in the same space of time; but although this might be taken as the average rate of discharge, the action of the ureters was by no means regular, inasmuch as two or three drops would sometimes flow in rapid succession, whilst, at other times, a comparatively long interval would elapse between the escape of any two. When the patient lay upon his back, the discharge was slow and gentle, being unattended with the distinct opening and shutting of the end of the tube noticed when in the upright position. During a deep inspiration, as in yawning or coughing, or whilst straining at stool, the flow of urine was suddenly increased, and the fluid escaped in a small stream, or in several large drops, in rapid succession. The urine itself was invariably acid, and often highly so, whilst the mucous membrane of the bladder possessed a highly alkaline reaction.

[1] Précis, &c., edit. cit., ii. 473.
[2] London Medical Gazette, 1845.

It was covered by a viscid glairy mucus, and was extremely sensitive to the touch.

Urine accumulates in the bladder until the desire arises to expel it: the number of times that a person in health and in the middle period of life, discharges it in the twenty-four hours, varies: some evacuate the bladder but twice, others may be compelled to do so as many as twelve or fourteen times. Nine times, according to Dr. Thomas Thomson,[1] is a common number. The quantity discharged at a time varies. The greatest observed by Dr. Thomson was 25½ cubic inches or somewhat less than a pint; the most common from seven to nine cubic inches. During its stay in the bladder, it is believed to be deprived of some of its more aqueous portions by absorption, and to become of greater specific gravity, and more coloured: it is here that depositions are apt to take place, which constitute *calculi;* although they are met with in the kidneys and ureters also.

As in every excretion, a sensation first arises, in consequence of which the muscles required for the ejection of the secreted matter are called into action. This sensation occurs whenever the urine has accumulated to the necessary extent, or when it possesses irritating qualities, owing to extraneous substances being contained in, or deposited from it; or if the bladder be unusually irritable from any morbid cause, the sensation may be repeatedly—nay, almost incessantly—experienced. The remarks that have been made on the sensations accompanying the other excretions are equally applicable here. The impression takes place in the bladder; whence it is conveyed to the brain, which accomplishes the sensation; and, consecutively, the muscles, concerned in the excretion, are called into action by volition. Physiologists have differed regarding the power of volition over the bladder. Some have affirmed, that it is as much under cerebral control as the muscles of locomotion; and they have urged, in support of this view, that the bladder receives spinal nerves, which are voluntary; that it is paralysed in affections of the spinal marrow, like the muscles of the limbs; and that a sensation, which seems destined to arouse the will, is always the precursor of its action. Others again have denied, that the muscular fibres are contractile under the will; and they adduce the case of other reservoirs,—the stomach and rectum, for example,—whose influence in excretion we have seen to be involuntary; as well as the fact that we feel the contraction of the bladder no more than we do that of the stomach or intestines; and they affirm, that the action of the bladder itself has been confounded with that of the accessory muscles, which are manifestly under the influence of the will, and are important agents in the expulsion of fluid from the bladder. The views, last expressed, appear to be most accurate, and the catenation of phenomena seems to be as follows:—the sensation to expel the urine arises; the abdominal muscles are thrown into contraction by volition; the viscera are thus pressed down upon the pelvis; the muscular coat of the bladder is, at the same time, stimulated by reflex action to contraction; the levatores ani and the sphincter fibres are relaxed, so that the resistance

[1] British Annals of Medicine, p. 6, Jan., 1837.

of the neck of the organ is diminished, and the urine is forced out through the whole extent of the urethra, being aided in its course, especially towards the termination, by the contractile action of the urethra itself, as well as by the levatores ani and acceleratores urinæ muscles. These expel the last drops by giving a slight succussion to the organ, and directing it upwards and forwards; an effect which is aided by shaking it to remove the drops that may exist in the part of the canal near its extremity. The gradually diminishing jet, which we notice as the bladder is becoming empty, indicates the contraction of the muscular coat of the organ; whilst the kind of intermittent jet, coincident with voluntary muscular exertion, indicates the contraction of the urethral muscles. When we feel the inclination to evacuate the bladder, and do not wish to obey it, the same muscles,—levatores ani, acceleratores urinæ, and the fibres around the membranous portion of the urethra and neck of the bladder,—are thrown into contraction, and resist that of the bladder.

Such is the ordinary mechanism of the excretion of urine. The contraction of the bladder is, however, of itself sufficient to expel its contents. M. Magendie[1] affirms, that he has frequently seen dogs pass urine when the abdomen was opened, and the bladder removed from the influence of the abdominal muscles; and he farther states, that if, in a male dog, the bladder, with the prostate and a small portion of the membranous part of the urethra, be removed from the body, the bladder will contract after a few moments, and project the urine, with an evident jet, until it is entirely expelled.

Urine, voided in the morning—*urina sanguinis*—by a person who has eaten heartily, and taken no more fluid than sufficient to allay thirst, is a transparent, limpid fluid, of an amber colour, saline taste, and peculiar odour. Its specific gravity is estimated by M. Chossat at from 1·001 to 1·038; by Cruikshank and Wagner,[2] from 1·005 to 1·033; by Prout, from 1·015 to 1·025; by Gregory, from 1·005 to 1·033; by Christison,[3] on the average, 1·024 or 1·025; by F. d'Arcet, from 1·001 to 1·060 [?],[4] by Rayer,[5] and Donné,[6] on the average, 1·018; by Dr. Bostock and M. Martin Solon,[7] 1·020; by Dr. Elliotson,[8] from 1·015 to 1·025; and Dr. Thomson[9] found it in an individual, from 50 to 60 years of age and in perfect health, on the average, 1·013; the lowest specific gravity, during ten days, being 1·004; and the highest, 1·026. Dr. Thomson has published tables[10] showing the quantity of urine passed at different times during ten days by the individual in question, and the specific gravity of each portion. These do not accord with the opinion generally entertained, that the heaviest urine is voided on rising in the morning. No generalization can, indeed, be made on

[1] Précis, ii. 474. [2] Elements of Physiology, by R. Willis, § 200, Lond., 1842.
[3] On Granular Degeneration of the Kidneys, p. 34, Edinb., 1839; or Amer. Med. Library edit., Philad., 1839.
[4] L'Expérience, No. lv., Aug., 1838.
[5] Traité des Maladies des Reins, &c., tom. i., Paris, 1839.
[6] Cours de Microscopie, p. 226, Paris, 1844.
[7] De l'Albuminurie, ou Hydropisie Causée par Maladie des Reins, Paris, 1838.
[8] Human Physiology, p. 293, Lond., 1835.
[9] British Annals of Medicine, p. 5, Jan., 1837. [10] Op. citat., p. 6.

the subject. The temperature of the urine, when recently passed, varied in one case from 92° to 95°. It is slightly acid, for it reddens vegetable blues. Although at first transparent, it deposits an insoluble matter on standing; so that urine, passed at bed-time, is found to have a light cloud—*enæorema*—floating in it by the following morning. This substance consists, in part, of mucus from the urinary passages; and, in part, of the super-lithate of ammonia, which is much more soluble in warm than in cold water.

According to Dr. Golding Bird,[1] three distinct varieties of urinary secretion may be recognised. *First.* That passed some little time after drinking freely of fluids, which is generally pale, and of low specific gravity—1·003 to 1·009—*urina potûs.* *Secondly.* That secreted after the digestion of a full meal, varying much in physical characters, and of considerable density—1·020 to 1·028, or even 1·030—*urina chyli* vel *cibi.* *Thirdly.* That secreted from the blood independently of the immediate stimulus of food and drink, as that passed after a night's rest—*urina sanguinis*—which is usually of average density—1·015 to 1·025—and presents in perfection the essential characters of urine.

The following table, drawn up, as far as 1032, by M. Becquerel, and completed from the observations of the last mentioned inquirer,[2] exhibits at a single inspection the amount of solids and water present in 1000 grains of urine of any particular density; so that from the quantity of urine passed in twenty-four hours it is easy to calculate how much solid matter the patient is parting with in that period.

Density.	Water in 1000 grains.	Solids in 1000 grains.	Density.	Water in 1000 grains.	Solids in 1000 grains.
1001	998·35	1·65	1029	960·4	39·6
1002	996·7	3·3	1026	957·1	42·9
1004	993·4	6·6	1028	953·8	46·2
1006	990·1	9·9	1030	950·5	49·5
1008	986·8	13·2	1032	947·2	52·8
1010	983·5	16·5	1034	943·9	56·1
1012	980·2	19·8	1036	940·6	59·4
1014	976·9	23·1	1038	937·3	62·7
1016	973·6	26·4	1040	934·	66·
1018	970·3	29·7	1042	930·7	69·3
1020	967·	33·	1044	927·4	72·6
1022	963·7	36·3	1046	924·1	75·9

Urine is extremely prone to decomposition. When kept for a few days it acquires a strong smell, which, being *sui generis*, has been called *urinous;* and as the decomposition proceeds, it becomes extremely disagreeable. As soon as these changes commence, it ceases to have an acid reaction. In a short time, a free alkali makes its appearance; and a large quantity of carbonate of ammonia is generated, and earthy phosphates are deposited. These phenomena are owing to the decomposition of urea, which is almost wholly resolved into carbonate of ammonia.

[1] Urinary Deposits, Amer. edit., p. 27, Philad., 1845.
[2] Lond. Med. Gazette, Feb. 10, 1843, p. 678.

The appearances presented by the urine under the microscope have, of late years, given rise to numerous investigations: they of course vary, according to the modifications it exhibits in health and disease. In the latter condition, much information has been collected, so that, according to M. Donné, the study of the urine may be said to be "the triumph of the microscope."[1] The morbid appearances, however, which it presents, do not belong to a work on physiology.

Dr. Henry[2] affirms, that the following substances have been satisfactorily proved to exist in healthy urine,—water, free phosphoric acid, phosphate of lime, phosphate of magnesia, fluoric acid, uric acid, benzoic acid, lactic acid, urea, gelatin, albumen, lactate of ammonia, sulphate of potassa, sulphate of soda, fluoride of calcium, chloride of sodium, phosphate of soda, phosphate of ammonia, sulphur and silex. One of the most elaborate analyses has been given by Berzelius.[3] He states it to consist—in 1000 parts—of water, 933·00; urea, 30·10; sulphate of potassa, 3·71; sulphate of soda, 3·16; phosphate of soda, 2·94; chloride of sodium, 4·45; phosphate of ammonia, 1·65; muriate of ammonia, 1·50; free lactic acid; lactate of ammonia; animal matter soluble in alcohol, and urea not separable from the preceding, 17·14; earthy phosphates, with a trace of fluoride of calcium, 1·00; lithic acid, 1·00; mucus of the bladder, 0·32; silex, 0·03. Dr. Prout[4] found 100 parts to consist of lithic acid, 90·16; potassa, 3·45; ammonia, 1·70; sulphate of potassa, with a trace of chloride of sodium, ·95; phosphate of lime, carbonate of lime, and magnesia, ·80; and animal matter, consisting of mucus and a little colouring matter, 2·94. M. Raspail[5] thinks it "possible" that uric acid is merely a mixture of organic matter (albumen) with an acid cyanide of mercury; so that the results of analysis may differ according as the analyzed substances may have been more or less separated from the organic matter. The physical and chemical characters of true uric acid, he thinks, accord very well with this hypothesis.

Elaborate researches have been undertaken by Liebig,[6] as regards the constitution of the urine,—whence he derives the following inferences. *First.* Neither lactic acid nor any lactate exists in healthy urine. *Secondly.* Hippuric acid is a constant constituent. *Thirdly.* The acid reaction of healthy urine is due to the presence of acid phosphate of soda. *Fourthly.* The acidity of urine is maintained and increased by the following changes. The urine of man and the carnivora has a large quantity of sulphates; but their food does not contain either those salts ready formed, or any oxygen compound of sulphur. The sulphur which it does contain, or which amounts to the same thing, the sulphur of the transformed tissues must, therefore, combine with oxygen in the body; and the sulphuric acid thus formed, uniting with

[1] Cours de Microscopie, p. 213, Paris, 1844.
[2] Elements of Experimental Chemistry, 9th edit., vol. ii. p. 435, Lond., 1823.
[3] Med. Chirurgical Transact., vol. iii.; Annals of Philos., ii. 423; and The Kidneys and Urine, by J. J. Berzelius, translated from the German, by M. H. Boyé, and F. Leaming, M. D., p. 97, Philad., 1843.
[4] Annals of Philos., v. 415.
[5] Op. citat., p. 507.
[6] Annalen der Chemie und Pharmacie, Mai, cited in London Lancet, June 1–8, 1844.

part of the alkali of the alkaline phosphates, forms acid phosphates. *Lastly.* It follows, that whether the urine be acid or not depends upon the nature and quantity of the bases taken with the food. If the amount be sufficient to neutralize the uric, hippuric, and sulphuric acids formed by the organism, and the acids supplied by the food, the urine must be neutral; if the amount be more than enough, the urine must be alkaline; if less, acid. Hence no physiological or pathological inference can be drawn from an examination of the urine, unless an account be taken of the inorganic acids, salts, and bases taken with the food. Some experiments have been made on the variations of the acidity of the urine in health by Dr. H. Bence Jones.[1] When a mixed diet was employed, the acidity of the urine was found to decrease soon after taking food, and to attain its lowest limit from three to five hours after meals. It then gradually increased, and attained its highest limit just before taking food. When animal food only was taken the diminution of acidity was more marked and more lasting; but the acidity before food did not rise quite so high as it did with the animal diet. When vegetable food was alone taken, the decrease in acidity was not to the same degree.

Notwithstanding the view of Liebig, that the uric acid of the urine is held in solution by the phosphate of soda, combining with a part of the base, and setting free a portion of the phosphoric acid, Dr. Golding Bird[2] adheres to the opinion of Dr. Prout, that uric acid is combined with ammonia. "Uric acid," he says, "at the moment of separation from the blood, meets the double phosphate of soda and ammonia derived from the food, and forms urate of ammonia, evolving phosphoric acid, which thus produces the natural acid reaction of the urine."

Healthy urine has been analyzed by Becquerel, Lehmann, Simon, Marchard, and Day. The analyses of Lehmann and Marchard approximate that of Berzelius; whilst those of Becquerel, Simon, and Day, agree pretty closely with each other.[3] The following are two of Simon's analyses:—

	I.	II.
Water,	963·00	956·000
Solid constituents,	36·20	44·00
Urea,	12·46	14·578
Uric acid,	0·52	0·710
Alcohol extract and lactic acid,	5·10	4·800
Spirit extract,	2·60	5·593
Water extract and mucus,	1·00	2·550
Lactate of ammonia,	1·03	
Chloride of ammonium,	0·41	
Chloride of sodium,	5·20	7·280
Sulphate of potassa,	3·00	3·508
Phosphate of soda,	2·41	2·330
Earthy phosphates,	0·58	0·654
Silica,	a trace	a trace.

[1] Philosophical Transactions for 1849, Pt. 2.

[2] Urinary Deposits, p. 48.

[3] Dr. Day's Report on Physiological and Pathological Chemistry, in Ranking's Abstract, Part i. p. 283, Amer. edit., New York, 1845.

M. Becquerel's analysis,[1] which has been adopted by Dr. Prout,[2] and by Dr. Golding Bird,[3] is as follows:—

Water,	967.
Urea,	14·230
Uric acid,	·468
Colouring matter, Mucus, and animal Extractive matter, } inseparable from each other,	10·167
Salts. { Sulphates, { Soda, Potash, ; Biphosphates, { Lime, Soda, Magnesia, Ammonia, ; Chlorides, { Sodium, Potassium, ; Hippurate of soda, ; Fluoride of potassium,	8·135
Silica,	traces
	1000·000

The yellowish-red incrustation, deposited on the sides of chamber utensils, is chiefly urate of ammonia. This is the basis of one of the varieties of calculi.

The quantity of urine passed in the twenty-four hours, is variable. Boissier states it at 22 ounces; Hartmann at 28; Dr. Robert Willis[4] at from 30 to 40; Prout at 32; Robinson at 35; Von Gorter at 36; Keill at 38; Rye at 39; Bostock at 40; Sanctorius at 44; Stark at 46; Dalton at 48½; Haller at 49; Christison at from 35 to 50; Becquerel at about 46; Dr. Thomas Thomson at 53; and Lining at from 56 to 59 ounces. On the average, it may be estimated perhaps at two pounds and a-half; hence the cause of the great size of the renal artery, which, according to the estimate of Haller, conveys to the kidney a sixth or eighth part of the whole blood. Its quantity and character differ according to age, and, to a certain extent, according to sex. We have already seen, under the head of *cutaneous exhalation*, how it varies, according to climate and season; and it is influenced by the serous, pulmonary, and areolar exhalations likewise: one of the almost invariable concomitants of dropsy is diminution of the renal secretion. Its character, too, is modified by the nature of the substances received into the blood. Rhubarb, turpentine, and asparagus alter its physical properties; whilst certain articles stimulate the kidney to augmented secretion, or are "diuretics."

The renal secretion may be considered as arising from different sources. When much fluid is taken, the amount of the urine is largely augmented, so that it is manifestly intended to remove superfluous fluid from the blood. It is also, as just shown, materially modified by certain ingesta; and not unfrequently the character of the food taken may be detected in it; hence, it has been conceived, the kidneys may have

1 Séméiotique des Urines, p. 7, Paris, 1841.

2 On the Nature and Treatment of Stomach and Renal Diseases, 4th edit., Amer. edit., p. 404, Philad., 1843.

3 Urinary Deposits, Amer. edit., p. 44, Philad., 1845.

4 Urinary Diseases and their Treatment, Bell's Library edit., p. 14, Philad., 1839.

the duty of removing from the system any crude or undigested elements of the food, which had been absorbed whilst traversing the small intestine, and entered the circulating mass; and of excreting the often noxious results of imperfect or unhealthy assimilation. Dr. Lehmann[1] instituted a series of experiments on himself, which afforded interesting information in regard to the varying composition of the urine, according as an animal, a vegetable, a mixed, or a non-nitrogenized diet was employed. On the mixed diet he lived fifteen days; ate and drank moderately; and abstained from all fermented liquors. He took an exclusively animal diet for twelve days, consuming thirty-two eggs each day. A purely vegetable diet was also continued for twelve days; but the non-nitrogenized was only taken for two days. In the following table the quantities of solid matter passed daily are represented by grammes (about $15\frac{1}{2}$ grains troy each); and also the proportional amount of salts and animal matter in that quantity of solid matter.

	Solid matter.	Urea.	Uric acid.	Lithic acid and salts.	Extractive matters.
Mixed diet -	67·82	32·498	1·183	2·257	10·489
Animal diet -	87·44	53·198	1·478	2·167	5·145
Vegetable diet -	59·24	22·481	1·021	2·669	16·499
Non-nitrogenized diet	41·68	15·408	0·735	5·276	11·854

Dr. Lehmann's results certainly show;—*first*, that animal food increases the solid matters in the urine, whilst vegetable substances, and especially non-nitrogenized aliments, diminish them:—*secondly*, that the proportion of nitrogen in the urine depends in part upon the kind of food taken,—food rich in nitrogen greatly increasing its amount. In his experiments, the proportion of urea to the other solid matters was as 100 to 116 under a mixed diet; as 100 to 63 under an animal diet; as 100 to 156 under a vegetable diet; and as 100 to 170 under a non-nitrogenized diet: *thirdly*, that the proportion of uric acid in the urine did not appear to have reference to the kind of food:—*fourthly*, that the urine contained quantities of sulphates and phosphates proportioned to the quantity of nitrogenized matters that had been absorbed: and, *fifthly*, that under an animal diet the quantity of extractive matters diminishes; whilst it is increased by the use of vegetable diet. These extractive matters contained, according to the researches of Liebig,[2] *kreatine* and *kreatinine*, two substances presumed to be derived from the metamorphoses of muscular tissues, and also a peculiar colouring matter derived probably from the hematin of the blood. Recent experiments by Dr. H. Bence Jones[3] confirm those of Lehmann in certain respects. They showed, that all food causes an increase in the amount of uric acid excreted; but that there was no great difference between animal and vegetable food in the production of such increase.

The urine does not appear to be intended for any local function. Its use seems to be restricted to the removal from the blood of the elements of the substances, of which it is composed; hence, it is solely

[1] L'Expérience, 7 Dec., 1843; cited in Edinb. Med. and Surg. Journal, April, 1844, and Art. Harn, Handwörterbuch der Physiologie, 7te Lieferung, s. 16, Braunschweig, 1844.

[2] Chemistry of Food, Lond., 1847.

[3] Philosophical Transactions, Pt. 2, for 1849.

depuratory and decomposing. How this decomposition is accomplished we know not. We have already referred to the experiments, performed by MM. Prévost and Dumas, Ségalas, Gmelin, Tiedemann and Mitscherlich, in which urea was found in the blood of animals whose kidneys had been extirpated: an inquiry has consequently arisen—how it exists there? Prior to these experiments, it was universally believed, that its formation is one of the mysterious functions executed in the intimate tissue of the kidney. It is proper to add, however, that neither MM. Prévost and Dumas, Tiedemann and Gmelin, nor M. Lecanu[1] could detect the smallest trace of this substance in the blood of animals placed under ordinary circumstances. Others, however, have affirmed, that it exists there normally, but in very small quantity. It is, according to Wöhler and Raspail, a cyanate of ammonia, and contains a very large proportion of nitrogen.

The general opinion of physiologists is, that the kidney is the outlet for an excess of nitrogen in the system in the same manner as the lungs and liver are outlets for superfluous carbon. The quantity of nitrogen, discharged in the form of urea, is so great, even in those animals whose food does not essentially contain this element, that it has been conceived a necessary ingredient in the nutrition of parts, and especially in the formation of fibrin, which is a chief constituent of the blood, and of every muscular organ. The remarks made on the absorption of nitrogen during respiration indicate one mode in which it is received into the system; and it has been presumed, that the superfluous portion is thrown off in the form of urea. There are three great modes in which the nitrogen thrown off by the urine may be obtained: *first*, from the air of respiration; *secondly*, from the food; for compounds of protein are absorbed from the intestinal canal; and the nitrogen which is not required for the wants of the system is thrown off from the kidneys in the form of urea and uric acid; and *thirdly*, in the disintegration of the tissues constantly occurring in the system of nutrition. Whilst certain of the elements that are superfluous are thrown off by the lungs and liver, the kidneys separate and throw off the superfluous nitrogen. From the results of Dr. Lehmann's experiments, it has been inferred, that so long as the ingesta contain no nitrogen, the whole of that element in the urine must be attributed to the disintegration or waste of the tissues, and may fairly be taken as a measure of its amount. This, however, is by no means established. We have no positive proof that the nitrogen received into the circulation in respiration is foreign to the formation of the nitrogenized compounds contained in the urine. It has been found in the urine of man after long fasting; and in that of reptiles, which had not taken food for months. Besides serving as an outlet for the superfluous nitrogen, there is no question, that the excess of the sulphur and phosphorus, which have become oxidized in the organism, and converted into sulphates and phosphates by a union with bases, is removed from the system through the urinary secretion. The whole subject of the

[1] Etudes Chimiques sur le Sang Humain, Paris, 1837.

urine in its chemical and chemico-physiological, and chemico-pathological history is full of interest; and hence the attention paid to it at this time everywhere by the chemists especially, who have sufficiently shown that the determination of its exact constitution is one of the most abstruse subjects of organic chemistry.[1]

The removal of the constituents of the urinary secretion from the blood is all-important. Experiments on animals have shown, that if it be suppressed by any cause for about three days, death usually supervenes, and the dangers to man are equally imminent. Yet there are some strange cases of protracted suppression on record. Haller mentions a case in which no urine had been secreted for twenty-two weeks; and Dr. Richardson,[2] one of a lad of seventeen, who had never made any, and yet felt no inconvenience.

Connexion between the Stomach and Kidneys.

In consequence of the rapidity with which fluids received into the stomach are sometimes voided by the urinary organs, it has been imagined, either that vessels exist, which communicate directly between the stomach and bladder, or that the fluid passes through the intermediate areolar tissue, or through the anastomoses of lymphatics. Experiments of Mr. Erichsen,[3] which consisted in introducing certain substances, that are readily detected by appropriate tests, into the stomach, and noting their appearance in the urine, signally exhibit the rapidity of this transmission. The earliest period at which prussiate of potassa was detected was about one minute after being swallowed; and the longest, thirty-nine minutes,—the difference appearing to depend upon the presence or absence of food in the stomach at the time. When it was empty, the salt was discovered in from one to two and a half minutes; whilst, soon after a meal, it required from six and a half to thirty-nine minutes.

In support of the opinion, that a more direct passage exists, the assertion of M. Chirac,—that he saw the urinary bladder become filled with urine when the ureters were tied, and that he excited urinous vomiting by tying the renal arteries,—is brought forward. It has been farther affirmed, that the oil, composing a glyster, has been found in the bladder. Dr. Darwin,[4] having administered to a friend a few grains of nitrate of potassa, collected his urine at the expiration of half an hour, and had him bled. The salt was found in the urine, but not in the blood. Mr. Brande made similar experiments with prussiate of potassa, from which he inferred, that the circulation is not the only medium of communication between the stomach and urinary organs, without, however, indicating the nature of the supposed medium; and this view is embraced by Sir Everard Home,[5] and Drs. Wollaston, Marcet, and

[1] For the most recent investigations of R. Bunsen, Millon, Marchard, Allan and Bensch, Bernard and Barreswil, Strahl and N. Lieberkühn, Wöhler and Frerichs, &c., see Scherer, in Canstatt and Eisenmann's Jahresbericht über die Fortschritte in der Biologie im Jahre 1848, s. 88.

[2] Philos. Transact. for 1713.

[3] Dublin Medical Press, July 9, 1845, and Ranking's Abstract, Part ii. p. 241, Amer. edit., New York, 1846.

[4] Zoonomia, xxix. 3.

[5] Philosophical Transactions, xcviii. 51, and ci. 163, for 1808 and 1811; and Lectures on Comparative Anatomy, i. 221, Lond., 1814; and iii. 138, Lond., 1823.

others. Lippi,[1] of Florence, thinks he has found an anatomical explanation of the fact. According to him, the chyliferous vessels have not only numerous inosculations with the mesenteric veins, either before their entrance into the mesenteric glands, or whilst they traverse those organs; but, when they attain the last of them, some proceed to open directly into the renal veins, and into the pelves of the kidneys. At this place, according to him, the chyliferous vessels divide into two sets; the one, ascending, and conveying the chyle into the thoracic duct; the other, descending, and carrying drinks into the renal veins and pelves of the kidneys. He affirms, that the distinction between the two sets is so marked, that an injection sent into the former goes exclusively into the thoracic duct, whilst if it be thrown into the latter it passes exclusively to the kidneys. These direct vessels Lippi calls *vasa chylopoietica urinifera.*

A kindred and equally inconceivable view has been recently maintained by M. C. Bernard,[2] who affirms, that when he introduced prussiate of potassa into the intestine of an animal, he recognized it sooner in the renal vein than in the renal artery. To account for this he instituted a series of researches, from which he concludes, that liquids absorbed from the intestines, after passing through the portal system and arriving in the vena cava, instead of ascending towards the heart, descend into the renal veins, which convey them to the renal capillaries; so that a considerable portion of them is eliminated without passing into the general current of the circulation.

In regard to the assertions of Lippi, were they anatomical facts, it would obviously be difficult to doubt some of the deductions; other anatomists have not, however, been so fortunate as he; and, consequently, it may be well to make a few comments. Yet—as has been elsewhere seen—the communication between the abdominal lymphatics and veins has been recently maintained by Dr. Nuhn.[3] Some of these chylopoietica urinifera, Lippi affirms, open into the renal veins. This arrangement, it is obvious, cannot be invoked to account for the shorter route—the *royal road* to the kidney. The renal vessel conveys the blood back *from* the kidney, and every thing that reaches it from the intestines, must necessarily pass into the vena cava, and ultimately attain the kidney through the renal artery. The vessels, therefore, that end in the renal veins, must be put entirely out of the question, so far as regards the topic in dispute; and attention be concentrated upon those that terminate in the pelvis of the kidney. Were this termination proved, we should be compelled, as we have remarked, to bow to facts; but not having been so, it may be stated as seemingly improbable, that the ducts in question should take the circuitous course to the pelvis of the kidney, instead of the direct one to the bladder.

We know then, nothing anatomically, of any canal between the stomach and bladder; and have not the slightest evidence—positive or relative—in favour of the opinion, that there is any transmission of

[1] Illustrazioni Fisiologiche e Patologiche del Sistema Linfatico-Chilifero, &c., Firenz, 1825.
[2] Union Médicale, No. 116, cited in British and Foreign Medico-Chirurgical Review, for Jan., 1850, p. 246.
[3] Vol. i. p. 666.

fluid through the intermediate areolar tissue. There is, indeed, absolute testimony against it. MM. Tiedemann and Gmelin having examined the lymphatics and areolar tissue of the abdomen, in cases where they had administered indigo and essence of turpentine to animals, discovered no traces whatever of them, whilst they could be detected in the kidney. The *facts*, again, referred to by Chirac, are doubtful. If the renal arteries be tied, the secretion cannot be effected; yet, as we have seen, in the case of extirpated kidneys, urea may exist in the blood, and, consequently, urinous vomiting be possible. If the ureters be tied, the secretion being practicable, death will occur if the suppression be protracted; and, in such case, the secreted fluid may pass into the vessels, and readily give a urinous character to the perspiration, vomited matters, &c., &c. The experiments of Darwin, Brande, Wollaston, and others only demonstrate, that these gentlemen were unable to detect in the blood that which they found in the urine. Against the *negative* results attained by these gentlemen, we may adduce the positive testimony of M. Fodéra,[1] an experimentalist of weight, especially on those matters. He introduced into the bladder of a rabbit a plugged catheter, and tied the penis upon the instrument to prevent the urine from flowing along its sides. He then injected into the stomach a solution of ferrocyanuret of potassium. This being done, he frequently removed the plug of the catheter, and received the drops of urine on filtering paper. As soon as indications of the presence of the salt appeared in the urine by the appropriate tests,—which usually required from five to ten minutes after its reception into the stomach,—the animal was killed; and on examining the blood, the salt was found in the serum taken from the thoracic portion of the vena cava inferior, right and left cavities of the heart, aorta, thoracic duct, mesenteric glands, kidneys, joints, and mucous membrane of the bronchia. M. Magendie,[2] too, states, as the result of his experiments,—*First.* That whenever prussiate of potassa is injected into the veins, or is exposed to absorption in the intestinal canal, or in a serous cavity, it speedily passes into the bladder, where it can be readily recognised in the urine. *Secondly.* That if the quantity of prussiate injected be considerable it can be detected in the blood by reagents; but if it be small, it is impossible to discover it by the ordinary means. *Thirdly.* That the same thing happens if the prussiate of potassa be mixed with the blood out of the body. *Fourthly.* That the salt can be detected in the urine in every proportion.

We may conclude, therefore, with Dr. Hale,[3] who has written an interesting paper on this subject, that the existence of any more direct route from the stomach to the bladder than the circulatory system and the kidneys is disproved; and we must consider the absorption of fluids to be effected through the vessels described under Absorption of Drinks. The facts, referred to elsewhere, (p. 178,) which show the extreme rapidity of the circulation, materially facilitate our comprehension of these cases.

[1] Recherches Expérimentales sur l'Absorption et l'Exhalation, Paris, 1824.

[2] Précis, &c., ii. 477.

[3] Boylston Prize Dissertation for the years 1819 and 1821. Boston, 1821.

Such are the glandular secretions to be considered in this place. There are still two important secretions—

7. *The Spermatic Secretion,*

and

8. *The Lacteal Secretion,*

which will be investigated under the Functions of Reproduction.

GLANDIFORM GANGLIONS.

There are several organs,—as the spleen, thyroid, thymus, and supra-renal capsules,—which are termed glands—*vascular glands* and *glands without ducts*, by many anatomists; but by M. Chaussier *glandiform ganglions*. Of the uses of these we know little. Yet it is necessary, that the nature of the organs and their fancied functions should meet with notice. The offices of the thyroid, thymus, and supra-renal capsules,—being chiefly confined to fœtal existence,—will not require consideration here. Although they have no ducts, their minute arrangement greatly resembles that of the true glands;—and they are all perhaps concerned, in some manner, in lymphosis, or in the due elaboration of the circulating fluid.

a. *The Spleen.*

The *spleen* is a viscus of considerable size, situate in the left hypochondriac region, (Fig. 332,) beneath the diaphragm, above the left kidney, and to the left of the stomach. Its medium length is about four and a half inches; its thickness two and a half, and its weight about eight ounces.[1] Its absolute weight, and its weight in proportion to that of the whole body, increases rapidly, according to Huschke, after birth; and its proportionate weight soon attains its highest standard, so that, in the adult, it has not a decidedly greater proportion to the body than at birth; and in some cases even decreases. It varies between 1 to 235 and 1 to 240.[2] Its relation to the weight of the liver is proportionally greater in the adult than in the infant. It is of a soft texture, somewhat spongy to the feel, and easily torn; and in a very recent subject is of a grayish-blue colour; which, in a few hours, changes to purple, so that it resembles a mass of clotted blood. At its inner surface, or that which faces the stomach and kidney, a fissure exists, by which the vessels, nerves, &c., enter or issue from the organ.

The histology of the spleen has been much investigated of late. Its main anatomical elements have been considered to be:—1. The *splenic artery*, which arises from the cœliac, and after having given off branches to the pancreas and the left gastro-epiploic artery divides into several branches, which enter the spleen at the fissure, and ramify in the tissue of the organ; so that it seems to be exclusively formed by them. Whilst the branches of the artery are still in the duplicature of the gastro-splenic omentum, and before they ramify in the spleen, they furnish the vasa brevia to the stomach. The precise mode of termina-

[1] Gross, Elements of Pathological Anatomy, 2d edit., p. 674, Philad., 1845.

[2] The French translation of Jourdan says between 1 to 235 and 1 to 400,—Encyclop. Anatom. v. 172, Paris, 1845.

tion of the arteries in the spleen is unknown: their communication with the veins does not, however, appear to be as free as in other parts of the body, nor the anastomoses between the minute arteries as numerous. If, according to Assolant,[1] one of the branches of the splenic artery be tied, the portion of the spleen to which it is distributed dies; and if air be injected into one of these branches, it does not pass into the other; so that the spleen would appear to be a congeries of several distinct lobes; and in certain animals the lobes are so separated as to constitute several spleens. A similar appearance is occasionally seen in the human subject. 2. The *splenic vein* arises by numerous radicles in the tissue of the spleen: these become gradually larger, and less numerous, and leave the fissure of the spleen by three or four trunks, which ultimately unite with veins from the stomach and pancreas to form one, that opens into the vena portæ. It is without valves, and its parietes are thin. These are the chief constituents. 3. *Lymphatic vessels*, which are large and numerous. 4. *Nerves*, proceeding from the cœliac plexus: they creep along the coats of the splenic artery—upon which they form an intricate plexus—into the substance of the spleen. 5. *Areolar tissue*, which serves as a bond of union between these various parts; but is in extremely small quantity. 6. A *proper membrane*, which envelopes the organ externally; adheres closely to it, and furnishes fibrous sheaths to the ramifications of the artery and vein; keeping the ramifications separated from the tissue of the organ, and sending prolongations into the parenchyma, which gives it more of a reticulated than a spongy aspect. 7. Of *blood*, according to many anatomists; but blood differing from that of both the splenic artery and vein; containing, according to M. Vauquelin, less colouring matter and fibrin, and more albumen and gelatin, than any other kind of blood. This, by stagnating in the organ, is conceived to form an integrant part of it. Malpighi[2] believed it to be contained in cells; but others have supposed it to be situate in a capillary system intermediate to the splenic artery and vein.

Assolant and Meckel[3] believe, that the blood is in a peculiar state of combination and of intimate union with the other organic elements of the viscus, and with a large quantity of albumen; and that this combination of the blood forms the dark brown pulpy substance, contained in the cells formed by the proper coat, and which can be easily demonstrated by tearing or cutting the spleen, and scraping it with the handle of a knife. These cells and the character of the tissue of the spleen are exhibited in the marginal figure. (Fig. 358.) In addition to the pulp, there is an abundance of rounded corpuscles, varying in size from an almost imperceptible magnitude to a line or more in diameter. By Malpighi, these were conceived to be granular corpuscles, and, by Ruysch,[4] simply convoluted vessels. M. Andral[5] affirms, that by repeated washings, the spleen is shown to consist of an infinite

[1] Recherches sur la Rate. Paris, 1801.
[2] Op. Omnia, pars ii., Lond., 1687; and Op. Posthum, p. 42. Lond., 1697.
[3] Handbuch, &c., traduit par Jourdan, iii. 476, Paris, 1825.
[4] Meckel, op. citat.
[5] Précis d'Anatomie Pathologique, tom. ii. part i. p. 416, Paris, 1832.

Fig. 358.

Section of the Spleen.

number of cells, which communicate with each other, and with the splenic veins. The latter, when the inner surface of the large subdivisions of the splenic veins are examined, appear to have a great number of perforations, through which a probe passes directly into the cells of the organ. The farther the subdivisions of the vein examined are from the trunk, the larger are these perforations; and still farther on, the coats of the vein are not a continued surface, but are split into filaments, which do not differ from those forming the cells, and are continuous with them. M. Bourgery has maintained, that the fibrous envelope of the spleen sends off a multitude of lamellæ, which penetrate its interior, forming irregular spaces of unequal dimensions. These short spaces he calls *splenic vesicles*. In the septa, a number of lymphatic glands exists. The capillaries of the arteries communicate directly with those of the veins; but, according to M. Bourgery, there are, in addition, veins with patulous orifices. The interior of the vesicles is filled with a soft substance of a deep red colour, in which the small white corpuscles, discovered by Malpighi, are suspended. M. Mandl[1] suggests, that the white corpuscles may be analogous to the intestinal villi, in which the lymphatics originate by a cæcal extremity.

The structure of the spleen has been intimately investigated by Dr. Evans,[2] and by Professor Kölliker.[3] The organ, according to the former, is essentially composed of a fibrous membrane, formed of white fibrous tissue, and in many of the lower animals having unstriped muscular fibres intermixed,[4] which constitutes its exterior envelope, and sends trabecular prolongations in all directions across its interior, so as to divide it into a number of irregularly shaped splenic cells, communicating freely with each other and with the splenic vein, and lined by a membrane continuous with that of the vein, which is so reflected upon itself as to leave oval or circular foramina, by which each cell communicates with the others and the vein. The diameter of these cells is estimated at from one-third to half a line, and they are generally traversed by filaments of elastic tissue, imbedded in which a minute artery and vein may frequently be observed. Over these fila-

[1] Manuel d'Anatomie Générale, p. 518, Paris, 1843.

[2] Lancet, April 6, 1844.

[3] Mittheilungen der Züricher Natürforschenden Gesellschaft vom Jahre, 1847; and art. Spleen, Cyclopædia of Anatomy and Physiology, pts. xxxvi. and xxxvii., June and October, 1849.

[4] Sharpey, in Quain and Sharpey's edition of Quain's Human Anatomy, by Leidy, ii. 498, Philad., 1849, Kölliker, op. citat.; and Ecker, art. Blutgefässdrüsen, Wagner's Handwörterbuch der Physiologie, 23ste Lieferung, s. 132, Braunschweig, 1849.

ments the lining membrane is reflected in folds; so that each cell is thus incompletely divided into two or more small compartments. No direct communication exists between the splenic artery and the interior of the cells; but its branches are distributed through the intercellular parenchyma, and the small veins, which collect the blood from the arterial capillaries of the organ, carry it into the cells whence it is conveyed away by the splenic vein. The cells may be readily injected from the vein with either air or liquid, provided they are not filled with coagulated blood; and they are so distensible—as has been long known—that the organ may be made, with very little force, to dilate to many times its original size. The cells of the spleen, according to Dr. Evans, never contain any thing but blood; and a frequent appearance after death is that of firmly coagulated blood filling them, and giving a granular aspect to the organ, which is sometimes described as morbid. The partitions between the cells are formed by the membranes already mentioned, and by the proper parenchyma of the spleen. To the eye it has a semi-fluid appearance, but when an attempt is made to tear it, considerable resistance is experienced, in consequence of its being intersected by what seem to be minute fibres. When a small portion is pressed, a liquid exudes—*liquor lienis* or splenic blood—which is usually described as filling the cells of the spleen; but according to Dr. Evans this is erroneous. This liquid, when diluted with serum, and examined under the microscope, is found to contain two kinds of corpuscles,—one apparently identical with ordinary blood corpuscles—the other with the corpuscles characteristic of lymph, and abundant in the lymphatic ganglions. The remaining fibrous substance consists wholly of capillary bloodvessels and lymphatics with minute corpuscles, much smaller than blood corpuscles, varying in size from about $\frac{1}{6000}$th to $\frac{1}{7000}$th of an inch, of spherical form, and usually corrugated on the surface. These lie in great numbers in the meshes of the sanguiferous capillaries; and the minute lymphatics are described by Dr. Evans as connected with the splenic corpuscles, and apparently arising from them. Lying in the midst of the parenchyma is a large number of bodies, of about a third of a line in diameter, which are evidently in close connexion with the vascular system. These are the *Malpighian bodies* of the spleen or *splenic corpuscles*. According to Dr. Evans, they, in all respects, resemble mesenteric or lymphatic ganglions in miniature—consisting, as they do, of convoluted masses of bloodvessels and lymphatics, united together by elastic tissue, so as to possess considerable firmness; and they farther correspond with them in this,—that the lymph they contain, which is quite transparent in the afferent vessels, becomes somewhat milky, from containing a large number of lymph corpuscles.

Professor Kölliker describes the spaces left by the trabecular prolongations as of irregular form and size, and occupied by the peculiar *splenic* or *Malpighian corpuscles*, and the splenic parenchyma. These corpuscles, according to him, are whitish spherical bodies, imbedded in the parenchyma of the spleen, but connected with the smaller arteries by short peduncles in a racemose manner. They are seldom seen in the human subject, owing to the rapid changes they undergo after

death; but Professor Kölliker has no doubt of their being invariably present in health. He affirms, that they have no relation to the lymphatics; but are closed capsules, resembling the elementary cells of glands before the rupture of their walls. The red *spleen substance*, *spleen pulp* or *parenchyma of the spleen*, consists in great part of cells, which correspond in appearance with those of the Malpighian corpuscles. Two other kinds, however, occur in it seldom met with in the latter; and numerous free nuclei are also present. Of these, one set bears a strong resemblance to red blood corpuscles; the others are pale with one or two nuclei, or colourless granule cells. A considerable part of the pulp appears to consist of blood corpuscles in various stages of metamorphosis, as was first taught by Professor Kölliker. "The blood globules"—he remarks—"first become at once smaller and darker, whilst the elliptical corpuscles of the lower vertebrata also become rounder; then, in connection with some blood plasma, they become aggregated into small round heaps; which heaps, by the appearance of an interior nucleus and of an outer membrane, experience a transition into spherical cells containing blood corpuscles. These are from 5-1000ths to 15-1000ths of a line in size, and contain from one to twenty blood corpuscles. During this time, the blood corpuscles are continually diminishing in size; and, assuming a golden yellow, brownish red or dark colour, they undergo, either immediately, or after a previous dissolution, a complete transition into pigment granules. So that these cells themselves are changed into pigmentary granule cells; and finally, by a gradual loss of colour of their granules, they form themselves into completely colourless cells."[1] These are found in the blood, especially of the splenic vein, vena portæ and inferior cava. It is not, however, easy to see how the corpuscles can leave the splenic arteries, unless they have a direct open communication with the splenic pulp, which is not admitted. Professor Kölliker describes the arterial branches as ramifying in the red spleen substance, where each twig subdivides into smaller and smaller arteries, and, when they become capillary, constitute a close and beautiful network in the splenic pulp. Giesker,[2] it is true, considers that the pulp consists of nothing but the minutest arteries and veins united by fibrous tissue. The whole subject, however, of splenic histology appears to the author to be far from determined, and to demand fresh investigations.

Besides the proper membrane, the spleen receives also a peritoneal coat; and, between the stomach and it, the peritoneum forms the *gastro-splenic epiploon* or *gastro-splenic ligament*, in the duplicature of which are situate the vasa brevia. Lastly; the spleen, as remarked above, is capable of distension and contraction; and is possessed of little sensibility in the healthy state. It has no excretory duct.[3]

The hypotheses, which have been indulged on the functions of the spleen, are beyond measure numerous and visionary; and, after all, we are in the greatest obscurity as to its real uses. Many of these hypo-

[1] Art. Spleen, &c., p. 782. [2] Cited by Kölliker, p. 790.

[3] A good epitome of the views of different observers in regard to the structure of the spleen, with observations of his own, is given by Dr. Wm. R. Sanders, in Goodsir's Annals of Anatomy and Physiology, No. 1, p. 49, February, 1850.

thesis are too idle to merit notice: such are those, that consider it to be the seat of the soul;—the organ of dreaming; of melancholy and of laughter, of sleep and the venereal appetite,—the organ that secretes the mucilaginous fluids of the joints, that serves as a warm fomentation to the stomach, and so on. It was long regarded as a secretory apparatus for the formation of atrabilis,—of a fluid intended to nourish the nerves,—of gastric juice,—of a humour intended to temper the alkaline character of the chyle or bile, &c. The absence of an excretory duct would be a sufficient answer to all these speculations, if the non-existence of the supposititious humours were insufficient to exhibit their absurdity. MM. Tiedemann and Gmelin[1] consider its functions to be identical with those of the mesenteric glands. They regard it as a ganglion of the absorbent system, which prepares a fluid to be mixed with the chyle and effect its animalization. In favour of the view, that it is a part of the lymphatic system, they remark, that it exists only in those animals that have a distinct absorbent system;—that its bulk is in a ratio with the developement of the absorbent system;—that the lymphatics predominate in the structure of the organ;—that its texture is like that of the lymphatic ganglions; and lastly, that on dissecting a turtle they distinctly saw all the lymphatics of the abdomen passing first to the spleen, then leaving that organ of larger size, and proceeding to the thoracic duct.

In support of their second position, that it furnishes some material towards the animalization of the chyle, they adduce,—the large size of the splenic artery, which manifestly, they conceive, carries more blood to the organ than is needed for its nutrition; and affirm, that, in their experiments, they have frequently found, whilst digestion and chylosis were going on, the lymphatic vessels of the spleen gorged with a reddish fluid, which was carried by them into the thoracic duct, where the chyle always has the most rosy hue; and that a substance injected into the splenic artery passes readily into the lymphatics of the spleen. Lastly, after extirpating the spleen in animals, the chyle appeared to them to be more transparent,—no longer depositing coagula; and the lymphatic ganglions of the abdomen seemed to have augmented in size. Views similar to these have been maintained by Sir Everard Home.[2]

M. Chaussier, as we have seen, classes the spleen amongst the *glandiform ganglions;* and affirms, that a fluid, of a serous or sanguineous character, is exhaled into its interior, which, when absorbed, assists in lymphosis. Many, again, have believed, that it is a sanguineous, not a lymphatic ganglion, but they have differed regarding the blood on which it exerts its action; some maintaining, that it prepares the blood for the secretion of gastric juice; others, for that of the bile. The former of these views is at once repelled by the fact, that the vessels which pass from the splenic artery to the stomach, leave that vessel before it enters the spleen. The latter has been urged by M. Voisin.[3] He thinks, the principal use of the spleen is to furnish to the liver blood

[1] Versuche über die Wege auf welchen Substanzen aus dem Magen und Darmkanal im Blut gelangen, p. 86, Heidelb., 1820.

[2] Philosoph. Transactions for 1808 and 1811: and Lect. on Comp. Anatomy, loc. cit.

[3] Nouvel Aperçu sur la Physiologie du Foie et les Usages de la Bile, Paris, 1833.

containing those materials that enter into the composition of the bile; but as to the changes produced on the blood, the greatest difference of sentiment has existed. Mr. Hewson[1] believed, that the spleen is the organ ordained by nature for "the more perfectly forming the red particles of the blood;" whilst Professor Kölliker infers from his observations—and Professor Ecker,[2] of Basle, accords with him,—that they suffer destruction or decomposition in the spleen, becoming changed in the manner before described; but in one that does not seem very intelligible. He supposes, that the altered corpuscles may be inservient to the formation of bile, the colouring matter of which is nearly allied to that of the blood, whilst the small nucleated cells of the Malpighian bodies may be concerned—it has been suggested—in the formation of fibrin. That some change is effected by the organ upon the blood sent to it by the splenic artery has long seemed to be confirmed by examination of that fluid.

Since the period of Haller, the blood of the splenic vein has been presumed to differ essentially from that of other veins, which naturally led to the belief, that some elaboration is effected in the spleen to fit the blood for the secretion of bile. It has been described as more aqueous, albuminous, and unctuous, and blacker than other venous blood; to be less coagulable, less rich in fibrin, and the fibrin it does contain to be less animalized. Yet these affirmations have been denied; and even were they admitted, we have no positive knowledge, that such changes adapt it better for the formation of bile. On the other hand, recent examinations by M. Béclard,[3] of the blood of the splenic veins and vena portæ seem to favour the views of Professor Kölliker. The following were the results of four successive bleedings of the same animal:—

	External Jugular.	Mammary.	Splenic.	Vena Portæ.
Water, - - -	778·9	750·6	746·3	702·3
Albumen, - - -	79·4	89·5	124·4	70·6
Red corpuscles and fibrin,	141·72	159·9	128 9	227·1

Farther analyses by the same gentleman showed a manifest diminution of the red corpuscles, and an increase of albumen and fibrin.[4]

The ideas that have existed, in regard to its acting as a diverticulum for the blood, have been mentioned under Circulation. By some, it has been supposed to act as such in the intervals of digestion; or in other words, to be a diverticulum to the stomach: by others, its agency in this way is believed to apply to the whole circulatory system, so that when the flow of blood is impeded or arrested in other parts, it is received into the spleen. Such a view was entertained by Dr. Rush,[5] and it has been embraced by many others.

It is hard to say which of these speculations is the most ingenious. None can satisfy the judicious physiologist, especially when he con-

[1] Works by Gulliver, Sydenham Society's edit., p. 273, Lond., 1846.
[2] Schmidt's Jahrbücher, u. s. w. No. 5, s. 146, Jahrgang. 1848, and art. Blutgefässdrüsen, in Wagner's Handwörterbuch der Physiologie, 23ste Lieferung, s. 152, Braunschweig, 1849; see, also, Dr. W. R. Sanders, Medical Times, April 21, 1849.
[3] Annales de Chimie et de Physique, xxi. 506, Paris, 1847.
[4] Comptes Rendus, xxvi. 122.
[5] Coxe's Medical Museum, Philad., 1807.

siders the comparative impunity consequent on extirpation of the organ. This was an operation performed at an early period. Pliny affirms, that it was practiced on runners to render them more swift. From animals the spleen has been repeatedly removed; and although many of these died in consequence of the operation, several recovered. M. Adelon[1] refers to the case of a man who was wounded by a knife under the last false rib of the left side. Surgical attendance was not had until twelve hours afterwards; and as the spleen had issued at the wound, and was much altered, it was considered necessary to extirpate it. The vessels were tied; the man got well in less than two months, and has ever since enjoyed good health. Sir Charles Bell[2] asserts, that an old pupil had given him an account of his having cut off the spleen in a native of South America. The spleen had escaped through a wound, and had become gangrenous. He could observe no effect from the extirpation. T. Chapman,[3] Esq., of Purneah, in India, has related a case of excision of a portion of the spleen by Dr. Macdonald of that station. A native, about thirty years of age, was gored in the abdomen by a buffalo; and through the wound, which was about three inches in length, a portion of the spleen protruded. Six days afterwards, the man sought advice from Dr. Macdonald, who removed the spleen with a knife, and the patient rapidly recovered.

Dr. O'Brien, in an inaugural dissertation, published at Edinburgh in 1818, refers to a case which fell under his own management. The man was a native of Mexico: owing to a wound of the abdomen, the spleen lay out for two days before the surgeon was applied to. The bleeding was profuse; the vessels and other connexions were secured by ligature, and the spleen separated completely on the twentieth day of the wound. On the forty-fifth day, the man was discharged from the hospital cured; and he remarked to some one about this time, that "he felt as well as ever he did in his life." The case of a man has been reported, who lived in good health for thirteen years after the spleen had been removed;[4] and another by M. Berthet de Gray of a middle-aged man, who received a wound in the side, through which the spleen eventually protruded, and becoming gangrenous, was removed. The man recovered, and lived thirteen years, enjoying sound health, his digestion being generally good. After death from pneumonia, all that remained of the spleen was found to be a small portion of the size of a filbert, adhering to the stomach.

Dulaurens, Kerckring, Baillie,[5] and others,[6] refer to cases, in which the spleen was wanting in man, without any apparent impediment to the functions, and the author has seen it in the dead body not larger than an almond, when there had been no reason to suspect splenic disease.

[1] Physiol. de l'Homme, 2de édit., tom. iii., Paris, 1829.
[2] Anat. and Physiol., 5th Amer. edit., by Dr. Godman, ii. 363, New York, 1827.
[3] India Journal of Medicine, vol. viii. p. 1; and London Medical Gazette for May 20, 1837, p. 285.
[4] Gazette Médicale de Paris, No. 28, 1844, cited from Oesterreich. Med. Wochenschrift, 21 Sept., 1844.
[5] Morbid Anatomy, 5th edit., p. 277, Lond., 1818.
[6] R. Lebby, Southern Journ. of Med. and Pharmacy, Sept., 1846.

The experiments, which have been made on animals, by removing the spleen, have led to discordant results. Malpighi says, that the operation was followed by increased secretion of urine; Dumas, that the animals had afterwards a voracious appetite; Mead and Mayer, that digestion was impaired; that the evacuations were more liquid, and the bile more watery; Tiedemann and Gmelin, that the chyle appeared more transparent and devoid of clot; Professor Coleman, that the dogs,—subjects of the experiment,—were fat and indolent. A dog, whose spleen was removed by Mr. Mayo,[1] became, on recovering from the wound, fatter than before: in a year's time it had returned to its former condition, and no difference was observed in its appearance or habit from those of other dogs. Similar results followed the experiments of Dr. Blundell, Mr. Dobson, and Mr. Eagle;[2] and the last gentleman states, that an offer had been made him of a "smart sum of money" by a dealer in Leadenhall Market, if he would tell him his method of fattening animals.

M. Dupuytren extirpated the spleen of forty dogs on the same day, without tying any vessel, but merely stitching up the wound of the abdomen,—yet no hemorrhage supervened! In the first eight days, half the dogs operated on died of inflammation of the abdominal viscera induced by the operation, as was proved by dissection. The other twenty got well without any accident, at the end of three weeks at the farthest. At first, they manifested a voracious appetite, but it soon resumed its natural standard. They fed on the same aliment, and drinks, took the same quantity of food, and digestion seemed to be accomplished in the same time. The fæces had the same consistence and appearance, and the chyle appeared to have the same character. Nor did the other functions offer any modification. M. Dupuytren opened several of the dogs some time afterwards, and found no apparent change in the abdominal circulation,—in that of the stomach, epiploon, or liver. The last organ, which appeared to some of the experimenters to be enlarged, did not seem to him to be at all so. The bile alone appeared a little thicker, and deposited a slight sediment. Similar experiments by Bardeleben[3] have led to results of an analogous kind. Animals, which survived the extirpation of the spleen, appeared to recover their health speedily, and to present no difference from those which had not undergone the operation. He never remarked, however, that they were more voracious than other animals. In no case was the organ regenerated. An animal deprived of both spleen and thyroid presented no change in any function,—a circumstance, which is in opposition to the view of Tiedemann, that the lymphatic ganglions and thyroid perform the functions of the spleen, when that organ has been extirpated. The incorrectness of the opinion of certain physiologists, that extirpation of the spleen causes augmentation of the venereal appetite, but abolition of the procreative power, was

[1] Outlines of Human Physiology, 4th edit., p. 107, Lond., 1838; and Outlines of Human Pathology, p. 128, Lond., 1836.
[2] Lond. Lancet, Oct. 8, 1842, p. 58, and Dec. 10, 1842, p. 406.
[3] Gazette Médicale de Paris, 23 Mars, 1844.

shown by M. Bardeleben, by breeding with dogs from which both spleen and thyroid had been removed.

Professor Mayer of Bonn[1] has affirmed that after the extirpation of the spleen, the small lymphatic ganglions in connexion with the splenic artery become enlarged, coalesce, and in no long time form masses of considerable size, which probably execute to a certain extent the functions of the extirpated organ. In ten months, in ducks and hens, a glandular mass existed, equal in size to the original spleen. This, he thinks, will account in part for the trifling disturbance of function resulting from extirpation of the organ.

It is impracticable, then, to arrive at any exclusive theory regarding the functions of this anomalous organ. Whilst it is probably inservient to lymphosis and to the purposes assigned it by Tiedemann and Gmelin; its office must be of a supplementary or vicarious nature; for it is manifestly not essential to life. It doubtless serves also as a diverticulum;—the blood speedily passing, after it has been extirpated, into other channels;—a view, which, as elsewhere remarked,[2] is somewhat confirmed by the splenic enlargements consequent on repeated attacks of intermittent,—the blood, which has receded from the surface, accumulating perhaps in this organ. It must be admitted, however, that our knowledge of the function is of a singularly negative and unsatisfactory character; and this is strikingly exemplified by the suggestion of Dr. Paley[3]—who was certainly not predisposed to arrive at such a conclusion—that the spleen "may be merely a stuffing, a soft cushion to fill up a vacuum or hollow, which, unless occupied, would leave the package loose and unsteady."

[1] London Med. Times, Mar. 25, 1845, p. 550.
[2] Practice of Medicine, ii. 103, 3d edit., Philad., 1848.
[3] Natural Theology, c. 11.

BOOK III.

REPRODUCTIVE FUNCTIONS.

The functions, which we have been hitherto considering, relate exclusively to the individual. We have now to investigate those that refer to the preservation of the species, and without which living beings would soon cease to exist. Although these functions are really multiple, it has been the custom with physiologists to refer them to one head —*generation*—of which they are made to form the subordinate divisions.

CHAPTER I.

GENERATION.

The function of generation, much as it varies amongst organized bodies, is possessed by them exclusively. When a mineral gives rise to another of a similar character, it is at the expense of its own existence; but the animal and the vegetable produce being after being without any curtailment of theirs.

The writers of antiquity considered, that all organized bodies are produced in one of two ways. Amongst the upper classes of both animals and vegetables, they believed the work of reproduction to be effected by a process, which is termed *univocal* or *regular generation*, (*generatio homogenea*, *propagatio*;) but in the very lowest classes, as the mushroom, worm, frog, &c., they conceived that the putrefaction of different bodies, aided by the influence of the sun, might generate life. This has usually been termed *equivocal* or *spontaneous generation*, (*generatio heterogenea*, *æquivoca*, *primitiva*, *primigena*, *originaria*, *spontanea*.) By some, however, *spontaneous generation* is made to include the production of living beings from the mere combination of inorganic elements; whilst by *equivocal generation* is meant their evolution from organized beings dissimilar to themselves, through irregularity in their functions, or the incipient decay or degeneration of their tissues. The doctrine of spontaneous generation is supposed to have been devised by the Egyptians to account for the swarms of frogs and flies, which appeared on the banks of the Nile after its periodical inundations.[1] Amongst the ancients, the latter hypothesis was almost universally credited. Pliny unhesitatingly expresses his belief, that the rat

[1] Fleming's Philosophy of Zoology, i. 24, Edinb., 1822.

and frog are produced in this manner; and in his time it was generally thought, that the bee, for example, was derived, at times from a parent; but at others from putrid beef.[1] The passage of Virgil[2]—in which he describes how the shepherd Aristæus succeeded in producing swarms of bees from the entrails of a steer, exposed for nine days to putrefaction—is probably familiar to most readers, and exhibits the same belief.

The hypothesis of equivocal generation having been conceived in consequence of the impracticability of tracing ocularly the function in the minute tribes of animals, it naturally maintained its ground uninterruptedly, as regarded those animals, until better means of observation were invented. The difficulty of admitting regular generation as applicable to all animals was augmented by the fact, not at first known to naturalists, that many of the lower tribes conceal their eggs, in order that their nascent larvæ may find suitable food; but the existence of evident sexual organs in many of these small species induced physiologists, at an early period, to believe, that they also might be reproduced by sexual intercourse: direct proofs were not, however, obtained until the discovery of the microscope; after which the investigations of Redi, Vallisnieri, Swammerdam, Hooke, Réaumur, Bonnet, and others, clearly demonstrated, that many of the smallest insects have eggs and sexes, and reproduce like other animals. In the case of plants it has been supposed, that the growth of fungi amongst dung, and of the various parasitical plants that appear on putrid flesh, fruit, &c., furnishes facts in support of the equivocal theory; but the microscope exhibits the seeds of many of these plants, and experiments show them to be prolific. The characters, by which the different species and varieties are distinguished, although astonishingly minute, are fixed, exhibiting no fluctuation, such as might be anticipated did the plants arise by spontaneous generation, or by the fortuitous concourse of atoms.

The animalcules, that make their appearance in water in which vegetable or animal substances have been infused or are contained, would seem, at first sight, to favor the ancient doctrine. In these cases, however, the species, again, have determinate characters; presenting always the same proportion of parts; and appearing to transmit their vitality to their descendants in a manner not unlike animals and vegetables higher in the scale. The explanation, offered by the supporters of the univocal theory for those obscure cases, in which direct observation fails us, is, that their seeds and eggs are so extremely minute, that they can be borne about by the winds, or by birds; be readily deposited; and, when they find a soil or nidus favourable to their growth, undergo developement. Thus, the soil, in which alone the *monilia glauca* flourishes, is putrid fruit; whilst the small infusory animal—*vibrio aceti* or vinegar eel—requires, for its growth, vinegar that has been for some time exposed to the air.[3] "That the atmosphere," says Dr. Good,[4] "is

[1] "Apes nascuntur partim ex apibus, partim ex bubulo corpore putrefacto."—Varro, De Re Rusticâ, iii. 16. See, also, Plinii Hist. Natural.

[2] Georgic. lib. iv. l. 295. See, also, J. B. Porta, Magiæ Naturalis libri viginti, cap. 2. "Animalia quædam terrestria, quæ ex putrefactione gignuntur." Lugd. Bat., 1644.

[3] Fleming, op. citat., p. 24.

[4] Study of Medicine, Cl. i. Ord. 1, Gen. x. Sp. 3.

freighted with myriads of insect eggs, that elude our senses; and that such eggs, when they meet with a proper bed, are hatched in a few hours into a perfect form, is clear to any one who has attended to the rapid and wonderful effects of what, in common language, is called a *blight*, upon plantations and gardens. I have seen, as probably many, who may read this work, have also, a hop-ground completely overrun and desolated by the *aphis humuli* or *hop green-louse*, within twelve hours after a *honey-dew* (which is a peculiar haze or mist, loaded with a poisonous miasm) has slowly swept through the plantation, and stimulated the leaves of the hop to the morbid secretion of a saccharine and viscid juice, which, while it destroys the young shoots by exhaustion, renders them a favourite resort for this insect, and a cherishing nidus for the myriads of little dots that are its eggs. The latter are hatched within eight-and-forty hours after their deposit, and succeeded by hosts of other eggs of the same kind; or, if the blight takes place in an early part of the autumn, by hosts of the young insects produced viviparously; for in different seasons of the year, the aphis breeds both ways. Now it is highly probable, that there are minute eggs or ovula of innumerable kinds of animalcules floating in myriads of myriads through the atmosphere, so diminutive as to bear no larger proportion to the eggs of the aphis than these bear to those of the wren, or the hedge-sparrow; protected, at the same time, from destruction by the filmy integument that surrounds them, till they can meet with a proper nest for their reception, and a proper stimulating power to quicken them into life; and which, with respect to many of them, are only found obvious to the senses in different descriptions of animal fluids. The same fact occurs in the mineral kingdom: stagnant water, though purified by distillation and confined in a marble basin, will, in a short time, become loaded on its surface or about its sides with various species of confervas; while the interior will be peopled with microscopic animalcules. So, while damp cellars are covered with boletuses, agarics and other funguses, the driest brick walls are often lined with the lichens and mosses. We see nothing of the animal and vegetable eggs or seeds by which all this is effected; but we know, that they exist in the atmosphere, and that this is the medium of their circulation." Any difficulty that might exist in regard to the transmission of such minute bodies through the atmosphere is removed, when we reflect on the extreme diffusion of odours, and on the fact that particles of sand are transmitted hundreds of miles from their original seat (see vol. i. p. 164). In dust, which was collected on a vessel three hundred miles from the land, Mr. Darwin[1] was much surprised to find particles of stone above the thousandth of an inch square, mixed with finer matter.

The view of the extraneous origin of the seeds of the confervæ, &c., is corroborated by an experiment of Senebier. He filled a bottle with distilled water, and corked it accurately; not an atom of green matter was produced, although it was exposed to the light of the sun for four years; nor did the green matter, considered as the first stage of spon-

[1] Journal of Researches into the Natural History and Geology of the Countries visited during the Voyage of H. M. S. Beagle round the World. By C. Darwin, M. A., F. R. S., Amer. edit., p. 7, New York, 1846.

taneous organization, exhibit itself in a glass of common water, covered with a stratum of oil. It is proper, however, to remark, that the observation of others invalidates the results of this experiment; and, moreover, it has been said, that if the fact be admitted, the exclusion of air might have prevented some simple condition necessary for the aboriginal developement of life. Burdach,[1] assisted by Hensche, and along with Professor von Baer, poured water on marble in a glass vessel, the remainder of the vessel being filled with atmospheric air, oxygen or hydrogen; and placed it in the light of the sun, or in warm sand. No green matter was perceptible, but there was a slimy substance with white threads, part of which had a ramified appearance, and part that of coral. On the other hand, pieces of granite, newly broken from the midst of a block, produced—with fresh distilled water, and oxygen or hydrogen, in the sun—green matter, with threads of confervæ; but in the warmth of digestion flocculi only. He next took some mould, which he dug up, and which was inodorous, and apparently free from all foreign matter; boiled it in a considerable quantity of water, and reduced the decoction to the consistence of a thick, partly pulverulent extract. This gave, with common water and atmospheric air—in bottles with ground stoppers, tied over with bladder—in the sun, numerous infusory animalcules and green matter; but with distilled water and oxygen or hydrogen, green matter only appeared at the bottom of the bottles.

The subject of intestinal worms has been eagerly embraced by the supporters of the doctrine of equivocal generation, who are of opinion, that the germs need not be received from without; whilst the followers of the univocal doctrine maintain, that they must always be admitted into the system. The first opinion includes amongst its supporters the names of Needham,[2] Buffon, Patrin, Treviranus,[3] Rudolphi,[4] Bremser,[5] Himly, and other distinguished helminthologists. The latter comprises those who believe in the Harveian maxim,—*omne vivum ex ovo.* To support the latter opinion, it has been attempted to show, that the worms, found in the human intestines, are precisely the same as others that have been found out of the body; but the evidence in favour of this position is by no means strong or satisfactory. Linnæus affirms, that *tænia vulgaris*,—of a smaller size, however,—has been met with in muddy springs; and *ascarides vermiculares* in marshes, and the putrescent roots of plants. Gadd affirms, that he met with *tænia articulata plana osculis lateralibus geminis* in a chalybeate rivulet; Unzer, *tænia* in a well; and Tissot says, that he found *tænia*, exactly like the human, in a river; whilst Linnæus, Leeuenhoek, Schäffer and others affirm, that they have found *distoma hepaticum* in water; but O. F. Müller,—who took extraordinary pains in the comparative examination of the entozoa that infest the human body, and those met with in springs,—

[1] Die Physiologie als Erfahrungswissenschaft, 2te Auflage, i. 23, Leipz., 1835.
[2] An Account of some New Microscopical Discoveries, 8vo, Lond., 1745.
[3] Biologie, ii. 264.
[4] Entozoorum sive Vermium Intestinalium Historia Naturalis, i. 370.
[5] Ueber Lebende Würmer im Lebenden Menschen, Wien, 1819.

states, that he has frequently detected *planariæ*, but never saw one like the *distoma hepaticum*.[1]

On the other hand, the supporters of the equivocal theory have laboured, with a good deal of success, to show, that a difference is always discoverable between the worms found without, and those found within, the body; but were it demonstrated to a mathematical certainty, that such difference exists, it would not be an invincible argument against the correctness of the univocal theory; as difference of locality, food, &c., might induce important changes in their corporeal developement, and give occasion to the diversity occasionally perceptible amongst these parasites. Yet if we admit, that the germs of the entozoa are always received from without, their occurrence in different stages of developement in the fœtus in utero is a circumstance difficult of explanation. Small, indeed, must be the germ, which, when received into the digestive organs of the mother, can pass into her circulation, be transmitted into the vessels of the fœtus; be deposited in some viscus, and there undergo its full developement; yet such cases have occurred, if the theory be correct. Certain it is,—howsoever the fact may be accounted for,—that worms have been found in the fœtus by indiduals whose testimony cannot be doubted. Eschholz saw them in the egg of the hen. Fromann found *distoma hepaticum* in the liver of the fœtal lamb; Kerckring,[2] *ascarides lumbricoides* in the stomach of a fœtus six and a half months old; Brendel, *tæniæ* in the human fœtus in utero; Heim, *tæniæ* in the new-born infant; Blumenbach, *tæniæ* in the intestine of the new-born puppy; and Göze, Bloch, and Rudolphi, the same parasite in sucking lambs.

Perhaps the conclusion of Cuvier[3] is most consistent with analogy, —that these parasites "propagate by germs so minute as to be capable of transmission through the narrowest passages; so that the germs may exist in the infant at birth." We have seen, however, that not simply the germs, but the animals themselves have been found at this early period of existence. The scientific world was, at one time, astounded by the assertion of Mr. Crosse, that he had succeeded in forming infusory animalcules from solutions of granite, silex, &c., by the aid of galvanism. He was engaged in some experiments on crystallization, in which a powerful galvanic battery was made to act upon a saturated solution of silicate of potassa, when the insects made their appearance. He subsequently employed nitrate of copper—a poison to mammalia—and from it also the insects emerged. Some years afterwards, these experiments were repeated by Mr. Weekes, of Sandwich, England, and with the same results. Besides employing silicate of potassa, Mr. Weekes tried ferrocyanuret of potassium, on account of its containing a larger proportion of carbon, a principal element of organized bodies; and from this the insects were produced in increased numbers. The insects produced by both experimenters appear to have been the same—a species of acarus, minute, semi-transparent, and furnished with long bristles, which can only be seen by the aid of the microscope.

[1] Rudolphi, op. citat. [2] Spicilegium Anatom. Obs., lxxix. p. 154, Amstel., 1670.
[3] Règne Animal, p. 27. See, also, Vogel, The Pathological Anatomy of the Human Body, by Day, p. 454, Lond., 1847, or Amer. edit., Philad., 1847.

The only satisfactory mode of explaining the phenomenon—difficult of conception under any aspect—is, that ova were existent in the solutions, which became developed under the galvanic influence. It has been plausibly argued, however, that the *Acarus Crossii* was a type of being ordained from the beginning, and destined to be realized under certain physical conditions. "When a human hand," observes a recent ingenious and able writer,[1] "brought these conditions into the proper arrangement, it did an act akin to hundreds of familiar ones which we execute every day, and which are followed by natural results; but it did nothing more. The production of the insect, if it did take place as assumed, was as clearly an act of the Almighty himself, as if he had fashioned it with his hands. For the presumption, that an act of aboriginal creation did take place there is this to be said, that, in Mr. Weekes's experiments, every care that ingenuity could devise, was taken to exclude the possibility of a developement of the insects from ova. The wood of the frame was baked in a powerful heat; a bell-shaped glass covered the apparatus, and from this the atmosphere was excluded by the constantly rising fumes from the liquid, for the emission of which there was an aperture so arranged at the top of the glass, that only these fumes could pass. The water was distilled and the substance of the silicate had been subjected to a white heat. Thus, every source of fallacy seemed to be shut off. In such circumstances, a candid mind, which sees nothing impious or unphilosophical in the idea of a new creation, will be disposed to think, that there is less difficulty in believing in such a creation having actually taken place, than in believing that in two instances, separated in time and place, exactly the same insects should have chanced to arise from concealed ova, and these a species heretofore unknown." For years, we are informed,[2] Mr. Weekes continued to subject solutions to electric agency, and invariably found insects produced in them, whilst they as invariably failed to appear where electric action was not employed, but every other condition was fulfilled. It is stated, however, in answer to these experiments, that specimens of the insects were sent to Paris, and found to contain ova; and that other specimens sent to London were discovered not to be a new species, but one abundant in the country,—"the *acarus horridus*, which abounds in dirty shops, dusty shelves, and damp outhouses; and having a taste for pure physics, is especially abundant in all laboratories, and among the bottles of a chemist's shop."![3]

Another series of facts has been brought forward as deserving not less attention than those already mentioned, and which would seem to show, that new species of animals may result from new circumstances. The pig, in its domestic state, is subject to the attacks of hydatids, from which the wild animal is free, and which constitute the "measles" in pork; and it is argued that as the domestication of the pig is comparatively a recent event, the hydatid must likewise be of recent origin. So, also, there is a tinea, which attacks dressed wool, but never touches

[1] Vestiges of the Natural History of Creation, Amer. edit., p. 143, New York, 1845.

[2] Sequel to Vestiges of the Natural History of Creation, p. 85, New York, 1846.

[3] Edinburgh Review, for July, 1845, Amer. edit., p. 38.

it in its unwashed state. A particular insect disdains all food but chocolate, and the larva of the *oinopota cellaris* lives no where but in wine and beer—all articles manufactured by man.[1] The subject is involved in difficulties; yet the univocal theory is, in all respects perhaps, most admissible as regards the whole living creation. "That all animals are produced from eggs (*omne vivum ex ovo*)," says Professor Agassiz,[2] "is an old adage in zoology, which modern researches have fully confirmed." Still, there are many distinguished naturalists who esteem it probable, that spontaneous generation may occur in the lowest divisions of the animal series. Amongst these may be mentioned De Lamarck, Raspail, Burdach, Treviranus, Wrisberg, Schweigger, Gruithuisen, Von Baer,—and M. Adelon seems to accord with them. The facts that have been observed, of late, of certain parasites, as the Cercaria, insinuating themselves into the skin and cavities of animals, as well as phenomena like the following, are favourable to the former view. At certain periods of the year, the sculpins of the Baltic are infested by a particular species of tænia, from which they are free at other seasons. Mr. Eschrich observes, that at certain seasons, these worms lose a great portion of the long chain of rings of which they are composed; and on a careful examination each ring is found to contain several hundred eggs, which, on being freed from their envelope, float in the water, and are doubtless swallowed by the sculpins, in which, finding a nidus favourable to their developement, the species is propagated, and transmitted from one generation of the fish to another.[3] All animals may swallow, in like manner, in their food and the water they drink, numerous eggs of parasites, which may become developed internally when the nidus is favourable to them; and it is probable that the intestines of man afford such a nidus only for the entozoa with which he is known to be infested; and hence we can account for the different parasites that are met with in different animals.

The views of M. De Lamarck[4] regarding the formation of living bodies are strange in the extreme; and exhibit, what we so frequently witness, that, in order to get rid of a subject difficult of comprehension, the philosopher frequently adopts suppositions, that require a much greater stretch of the imagination to invent, and present stronger obstacles to belief, than those for which they may have been substituted. M. De Lamarck maintains, that the first organized beings were formed throughout by a true spontaneous generation,—their existence being owing to an excitative cause of life, furnished probably by the circumambient medium, and consisting of light and electric fluid. When this cause meets with a substance of a gelatinous consistence, dense enough to retain fluids, it organizes it into areolar tissue; and a living being results. This process, according to De Lamarck, is occurring daily at the extremity of the vegetable and animal kingdoms. The being, thus formed, manifested originally, according to him, three faculties of life; nutrition, growth, and reproduction; but only in the most simple

[1] Vestiges, &c., p. 139.
[2] Principles of Zoology, by Louis Agassiz and Augustus A. Gould, p. 103, Boston, 1848.
[3] Agassiz and Gould, op. cit., p. 141.
[4] Philosophie Zoologique, vol. i., Paris, 1830.

manner. The organization soon, however, became more complicated, for it is, he remarks, a property of the vital movement to tend always to a greater degree of developement of organization; to create particular organs, and to divide and multiply the different centres of activity: and, as reproduction has constantly preserved all that had been acquired, numerous and diversified species have in this manner been formed, possessing more and more extensive faculties. So that, according to this system, nature was directly concerned only in the first draughts of life; and participated indirectly in the existence of living bodies of a more complex character; and these proceeded from the former, after a lapse of an enormous time, and an infinity of changes in the incessantly increasing complication of organization;—reproduction continuing to preserve all the acquired modifications and improvements.

The simplest kind of generation does not require sexual organs. The animal, at a certain period of existence, separates into several fragments, which form so many new individuals. This is called *fissiparous generation* or *generation by spontaneous division.* We have examples of it in the infusory animalcules,—as in *vibrio aceti*, the vinegar eel. A somewhat more elevated kind of reproduction is the *gemmiparous*,—common in the vegetable kingdom,—which consists in the formation of buds, sporules, or *germs* on some part of the body. These, at a particular period, drop off, and form as many new individuals; and, according as the germs are developed at the surface of the body, or internally, gemmiparous generation is said to be *external* or *internal.* In these two varieties, the whole function is executed by a single individual. Higher up in the scale, we find special organs—*male* and *female*—for the accomplishment of generation. In animals, however, that possess special reproductive organs, some have both sexes in the same individual or are *hermaphrodite* or *androgynous*, as is the case with almost all plants, and some of the lower tribes of animals. In these, again, we notice a difference. Some are capable of reproduction without the concourse of a second individual; others, although possessing both attributes, require the concourse of another; the male parts of the one uniting with the female parts of the other. Both, in this way, become impregnated. The *helix hortensis* or *garden snail* affords us an instance of this kind of reproduction. They meet in pairs, according to Shaw,[1] and, stationing themselves an inch or two apart, launch several small darts, not quite half an inch long, at each other. These are of a horny substance, and sharply pointed at one end. The animals, during the breeding season, are provided with a little reservoir for them, situate within the neck, and opening on the right side. On the discharge of the first dart, the wounded snail immediately retaliates on its aggressor by throwing a similar dart; the other renews the battle and is wounded in turn. When the darts are expended, the war of love is completed, and its consummation succeeds.

In the superior animals, each sexual characteristic is possessed by a separate individual,—the species being composed of two beings, male

[1] Zoology, or Systematic Natural History, Lond., 1800.

and female; and the concourse of the two, or of matters proceeding from them, being absolutely necessary for reproduction. But here, again, two great differences are met with in the process. Sometimes the fecundating fluid of the male is not applied to the ovum of the female, until after its ejection by the latter, as in fishes. In other cases, the ovum cannot be fecundated after its ejection, and the fluid of the male sex is applied to it whilst still within the female—as in birds and the mammalia. In such case, the male is furnished with an organ for penetrating the parts of the female, and, in this kind of generation, there must be *copulation.*

Again, where there is copulation, the following varieties may exist. *First.* The ovum, when fecundated, may be immediately laid by the female, and be hatched out of the body,—constituting *oviparous generation. Secondly.* Although the process of laying may commence immediately, the fecundated ovum may pass so slowly through the excretory passages, that it may be hatched there; and the new individual issue from the womb of the parent possessing the proper formation. This constitutes *ovo-viviparous generation*, of which we have examples in the viper and salamander. *Thirdly.* The fecundated ovum may be detached from the ovary soon after copulation; but, in place of being ejected, may be deposited in a reservoir, termed a *womb* or *uterus;* be fixed there; attract fluids from the organ adapted for its developement; and thus, increasing at the expense of the mother, be hatched, as it were, in this reservoir so that the new being may be born under its appropriate form. In such case, it may be supported for a time, after birth, on a secretion of the mother—the milk. These circumstances constitute *viviparous generation;* in which there are copulation, fecundation, gestation or pregnancy, and lactation or suckling. *Lastly.* There are animals, which, like the kangaroo, opossum, and wombat, are provided with abdominal pouches—*marsupia*—into which the young, born at a very early stage of developement, are received; and nourished with milk secreted from the glands, contained within these pouches. Such animals are termed *marsupial* or *marsupiate.*

There is much difference in animals as regards the nurturing care afforded by the parents to their young. Amongst oviparous animals, many are satisfied with instinctively depositing their ova in situations and under circumstances favourable to their being hatched, and abandoning them, so that they can never know their progeny. This is the case with insects. Others, again, as birds, subject their ova to incubation; and, after they have been hatched, administer nourishment to their young during the early period of existence. In the viviparous animal, these cares are still more extensive,—the mother drawing from her own bosom the nutriment needed by the infant, or *suckling* it. There are yet other varieties in the generation of animals. In some, it can be performed but once during the life of the individual; in others, it can be effected repeatedly. At times, one copulation fecundates only a single individual; at others, several generations. A familiar example of this fecundity occurs in the common fowl, in which a single access may be sufficient to fecundate the eggs for a season. In the insect tribe, this is still more strikingly exemplified. In the *aphis*

puceron or *green plant louse*, through all its divisions; and in the *monoculus pulex*, according to naturalists, a single impregnation suffices for at least six or seven generations. There is, in this case, another strange deviation from the ordinary laws of propagation,—that in the warm summer months the young are produced viviparously; and in the cooler autumnal months oviparously. A single impregnation of the queen bee serves to fecundate all the eggs she may lay for two years at least,—Huber[1] believes for the whole of her life, but he has had numerous proofs of the former. She begins to lay her eggs forty-six hours after impregnation; and commonly lays about three thousand in two months, or at the rate of fifty daily. The young, again, are sometimes born with the shape they have always to maintain; at others, under forms that are subsequently modified materially, as in the *papilio* or *butterfly* genus;—and, *lastly;*—many naturalists admit a series of cases in which the young not only do not resemble the parent at birth, but remain dissimilar during their whole life, so that their relationship is not apparent until a succeeding generation. The son resembles not the father, but the grandfather; and in some cases the resemblance does not reappear until the fourth or fifth generation, and even later. This strange variety of propagation has received the name of *alternate reproduction* or *generation*. The phenomena presented by it have been much studied of late, and especially by Professor Agassiz. Among the parasitic worms is one known under the name Cercaria, which attaches itself to fresh-water shells, particularly the Lymnea and Paludina; and soon becomes changed into the Distoma or Fluke; so that the Cercaria can only be considered as the larve of the Distoma; and farther investigation exhibits even larves to the Cercaria themselves. Among the aphides the number of generations is still greater. The first generation, which is produced from eggs, soon undergoes metamorphosis, and gives birth to a second generation, which is followed by a third, and so on; so that it is not at times until the eighth or ninth generation, that the perfect animal appears as male and female,—the sexes being for the first time distinct, and the male provided with wings. The female lays eggs, which are hatched the following year to undergo a similar succession.[2]

Reproduction in the human species requires the concourse of both sexes; the sexes being separate, and each possessed by a distinct individual—*male* and *female*. All the acts comprising it may be referred to five great heads. 1. *Copulation*, the object of which is to apply the fecundating germ, furnished by the male, to that of the female. 2. *Conception* or *fecundation*, the prolific result of copulation. 3. *Gestation* or *pregnancy*, comprising the sojourn of the fecundated ovum in the uterus, and the developement it undergoes there. 4. *Delivery* or *accouchement*, which consists in the detachment of the ovum; its excretion, and the birth of the new individual: and lastly, *lactation*, or the nourishing of the infant on the maternal milk.

[1] Nouvelles Observations sur les Abeilles, Paris, 1814.
[2] Agassiz and Gould, op. cit., p. 131.

1. GENERATIVE APPARATUS.

The part, taken by the two sexes in the process of generation is not equally extensive. Man has merely to furnish the fluid necessary for effecting fecundation, and to convey it within the female. He, consequently, participates only in copulation and fecundation; whilst, in addition, the acts of gestation and lactation are accomplished by the female. Her generative apparatus is therefore more complicated, and consists of a greater number of organs.

a. *Genital Organs of the Male.*

The generative apparatus of the male comprises two orders of parts:—1. Those which secrete and preserve the fecundating fluid, and those which accomplish copulation. The first consists of two similar glands—*testes*—which secrete the *sperm* or fecundating fluid from the blood. 2. The excretory ducts of those glands—*vasa deferentia.* 3. The *vesiculæ seminales*, which communicate with the vasa deferentia and urethra; and 4. Two canals, called *ejaculatory*, which convey the sperm from the vesiculæ seminales into the canal of the urethra, whence it is afterwards projected externally. The second consists of the *penis*, an organ essentially composed of erectile tissues, and capable of acquiring considerable rigidity. The several parts will require a more detailed notice.

Testes.—The testicles are two glands situate in a bag suspended beneath the pubes, called *scrotum;* the right being a little higher than the left. They are of an ovoid shape, compressed laterally,—their size being usually that of a pigeon's egg, and weight about seven and a half or eight drachms:—Sir A. Cooper[1] says about an ounce; and Mr. Curling[2] six drachms. The left testis is generally larger than the right. Like other glands, they receive arterial blood by an appropriate vessel, which communicates with the excretory duct. The *spermatic artery* conveys the blood, from which the secretion has to be formed, to the testicle. It arises from the abdominal aorta at a very acute angle; is small, extremely tortuous, and passes down to the abdominal ring, through which it proceeds to the testicle. When it reaches this organ, it divides into two sets of branches, some of which are distributed to the epididymis, and others enter the testicle at its upper margin, and assist in constituting its tissue. The excretory ducts in the testicle form what are called the *seminiferous vessels* or *tubuli seminiferi.* These terminate in a white cord or nucleus—situate at the upper and inner part of the organ, where the excretory duct commences—which is called *corpus Highmorianum* or *sinus of the seminiferous vessels.* Besides these anatomical elements of the testes, there are also—1. Veins, termed *spermatic*, which return the superfluous blood to the heart. These arise in the very tissue of the organ, and form the *spermatic plexus*, the divisions of which collect in several branches, that pass through the abdominal ring, and unite into a single

[1] Observations on the Structure and Diseases of the Testis, Amer. edit., p. 25, Philad., 1845.

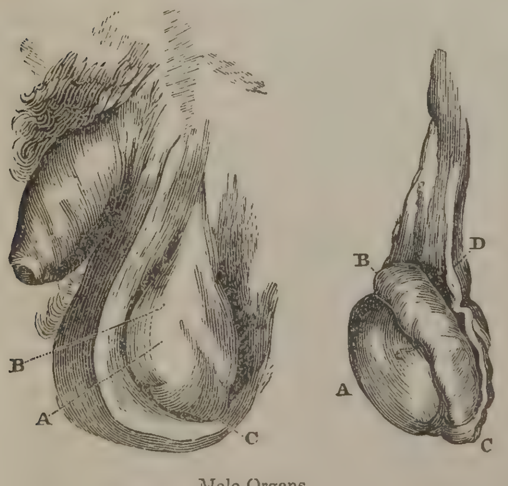
[2] Practical Treatise on Diseases of the Testis, &c., p. 9, Lond., 1843.

trunk, which subsequently divides again into another plexus, termed *corpus pampiniforme*. This has been described as peculiar to the human species, and as a diverticulum for the blood of the testicle, whose functions are intermittent. These veins ultimately terminate on the right side in the vena cava, and on the left in the renal vein. 2. Lymphatic vessels, in considerable number, the trunks of which, after having passed through the abdominal ring, open into the lumbar glands. 3. Nerves, partly furnished by the renal and mesenteric plexuses and by the great sympathetic, partly by the lumbar nerves, and which are so minute as not to be traceable as far as the tissue of the testicle. 4. An outer membrane or envelope to the whole organ, called *tunica albuginea* or *peritestis*. This is of an opaque white colour and of an evidently fibrous and close texture; it envelopes and gives shape to the organ, and sends into the interior of the testicle numerous filiform, flattened prolongations, which constitute incomplete septa. These form triangular spaces, filled with seminiferous vessels, which pass, with considerable regularity, towards the superior margin and corpus Highmorianum.

These elements united constitute the testicle, the substance of which is soft, of a yellowish-gray colour, and divided by prolongations of the tunica albuginea, and the tunica vasculosa of Sir A. Cooper, into a number of lobes and lobules. It seems to be formed of an immensity of very delicate, tortuous filaments, interlaced and convoluted in all directions, loosely united, between which are ramifications of the spermatic arteries and veins.

According to Dr. Monro, secundus,[1] the seminiferous tubes of the testicle do not exceed the $\frac{1}{200}$th part of an inch in diameter, and when filled with mercury, the $\frac{1}{120}$th part. He calculated, that the testis consists of 62,500 tubes, supposing each to be one inch long; and that if the tubes were united they would be 5208 feet four inches long. Lauth estimates their length at 1750 feet, and Krause at 1015. The tubuli seminiferi finally terminate in straight tubes, called *vasa recta*, which unite near the centre of the testis in a complicated arrangement, bearing the name *rete testis* or *rete vasculosum testis:* from this from 12 to 18 ducts proceed upwards and

Fig. 359.



Male Organs.

Left Hand Fig. Testicle covered by its membranes, and seeming like one body. *Right Hand Fig*. Testicle freed from its outer coat. A. Body of testicle. B. Commencement of epididymis, or *globus major*. C. Small head, or *globus minor*. D. *Vas deferens*. (Sir C. Bell.)

[1] Elements of the Anat. of the Human Body, by Monro, tertius, ii. 179, Edinb., 1825.

backwards to penetrate the corpus Highmorianum and tunica albuginea. These ducts are called *vasa efferentia.* Each of them is afterwards convoluted upon itself, so as to form a conical body, called *conus vasculosus*, having its base backwards; and at its base, the tube of each cone enters the tube of which the epididymis is formed. The epididymis is the prismatic arch, B, C, Fig. 359, which rests vertically on the back of the testicle, and adheres to it by the reflection of the tunica vaginalis, so as to appear a distinct part from the body of the testis. It is enlarged at both ends;—the upper enlargement being formed by the coni vasculosi, and called *globus major;* the lower called *globus minor.* The epididymis is formed by a single convoluted tube, a fourth of a line in diameter. When the tube attains the lower end of the globus minor, it becomes less convoluted, enlarges, turns upwards, and obtains the name *vas deferens.*

Fig. 360.

Human Testis injected with Mercury.

1, 1. Lobules formed of seminiferous tubes. 2. Rete testis. 3. Vasa efferentia. 4. Plexuses of efferent vessels passing into the head of the epididymis 5, 5. 6. Body of epididymis. 7. Its appendix. 8. Its tail or cauda. 9. Vas deferens. (Lauth.)

Into the angle made by the epididymis, where it terminates in the vas deferens, is poured the secretion of the appendix or *vasculum aberrans*, which closely resembles a single lobule in structure. It use is unknown.

The marginal figures exhibit the arrangement of the testis and its ducts.

The testes of most animals, that procreate but once a year, are comparatively small during the months when they are not excited. In man, the organ before birth, or rather during the greater part of

Fig. 361.

Plan of the Structure of the Testis and Epididymis.

a, a. Tubuli seminiferi. *a*, a**. Their anastomoses. *b.* Rete testis. *c.* Vasa efferentia. *d, d.* Plexus of efferent vessels passing into the head of the epididymis. *e, e, f.* Body of epididymis. *g.* Its appendix. *h.* Its tail or cauda. *i, i.* Vas deferens. (Lauth.)

gestation, is an abdominal viscus; but, about the seventh month of fœtal existence, it gradually descends through the abdominal ring into the scrotum, which it reaches in the eighth month by a mechanism to be described hereafter. In some cases it never descends, but remains in the cavity of the abdomen, giving rise to considerable mental distress in many instances; and exciting the idea, that there may be a total absence of the organs, or that if they exist they cannot effect the work of reproduction. The uneasiness is needless, provided there be other evidences of virility,—the descent appearing to be by no means essential. It has been sufficiently demonstrated, that individuals, so circumstanced, are capable of procreation. Few opportunities have occurred for observing the condition of the testes in such cases after death; but these have not exhibited any morphological defect, which could lead to the belief, that they were incapable of executing their functions. The parts of a gentleman, who committed suicide on account of the nondescent of the testes, are in the Museum of Guy's Hospital, London. Mr. Curling[1] examined the preparation, and found the testes, both of which were within the abdomen close to the internal ring, apparently nearly, if not quite, the natural size; and it is stated, that the ducts contained sperm. In many animals, the testicles are always internal; whilst, in some, they appear only in the scrotum during the season of amorous excitement. M. Foderé has indeed asserted, that the *crypsorchides* or *testicondi*,—those whose testes have not descended,—are occasionally remarked for the possession of unusual prolific powers and sexual vigour.[2] Dr. Marshall states, that in the examination of 10,800 recruits he found 5 in whom the right, and 6 in whom the left testicle was not apparent. He met with but one instance in which both testicles had not descended.[3]

It appears that there is a set of barbarians at the back of the Cape of Good Hope, who are generally possessed of but one testicle, or are *monorchides;* and Linnæus, under the belief, that this is a natural defect, has made them a distinct variety of the human species. Sir John Barrow noticed the same singularity; but Dr. Good[4] thinks it doubtful, whether, like the want of beard amongst the American savages, the destitution may not be owing to a barbarous custom of extirpation in early life. The deviation is not, however, more singular than the unusual formation of the nates and genital organs of the female in certain people of those regions, to which we shall have to refer. The possession of a single testicle appears to be sufficient for procreation. Occasionally three exist. At times, they are extremely small, but capable of executing all their functions. Mr. Wilson[5] was consulted by a gentleman, on the point of marriage, respecting the propriety of his entering into that state, whose penis and testicles very little exceeded

[1] Art. Testicle, in Cyclopædia of Anatomy and Physiology, Pt. xxxviii. p. 990, Feb. 1850.

[2] "Ces organes paraissant tirer du bain chaud où ils se trouvent plongés plus d'aptitude à la sécrétion que lorsqu'ils sont descendus au dehors dans leurs enveloppes ordinaires!"—*Traité de Médecine Légale*, i. 370, Paris, 1813.

[3] Hints to Young Medical Officers in the Army, p. 83.

[4] Physiological Proem to class Genetica, Study of Medicine, vol. iv.

[5] Lectures on the Structure and Physiology of the Male Urinary and Genital Organs, &c. London, 1821.

in size those of a youth of eight years of age. He was twenty-six years old, but had never experienced sexual desire until he became acquainted with the lady whom he proposed to make his wife; after which he had repeated erections, with nocturnal emissions. He married; became the father of a family; and when twenty-eight years old the organs had increased to the usual size of those of the adult.

In certain cases, the testes are drawn up against the abdominal ring so as to encourage the idea, that there are none in the scrotum. Professor Gross[1] has given the cases of two boys, one fourteen, the other eleven years of age, who were said to have been castrated; and a medical practitioner deposed to the absence of the testes; which, however, were found in the groin, a little below the external ring, whence, by a little traction, they could be easily drawn down into the scrotum.

The testicle is connected with the abdominal ring by means of the *spermatic cord*, a fasciculus of about half an inch in diameter, which can be readily felt through the skin of the scrotum. It is formed essentially of the vessels and nerves that pass to or from the testicles;—the spermatic artery, spermatic veins, lymphatics, and nerves of the organ, and the vas deferens, or excretory duct. These are bound together by means of areolar tissue; and, externally, a membranous sheath of a fibrous character envelopes the cord, and keeps it distinct from the surrounding parts, and especially from the scrotum. When the cord has passed through the abdominal ring, its various elements are no longer held together, but each passes to its special destination.

The *scrotum* or *purse* is a continuation of the skin of the inner side of the thighs, perineum, and penis. It is symmetrical, the two halves being separated by a median line or *raphe.* The skin is of a darker colour here than elsewhere; rugous; studded with follicles, and sparingly furnished with hair. This may be considered its outermost coat. Beneath this is the *dartos*,—a reddish, areolar membrane, which forms a distinct sac for each testicle; and a septum—*septum scroti*—between them. Much discussion has taken place regarding the nature of the dartos; some supposing it to be muscular, others areolar. Breschet and Lobstein affirm, that it does not exist in the scrotum before the descent of the testes, and they consider it to be formed by the expansion of the gubernaculum testis. Meckel, however, suggests, that it constitutes the transition between the areolar and muscular tissues, and that there exists between it and other muscles the same relation as between the muscles of the superior and inferior animals. It consists of long fibres considerably matted together, and passing in every direction, but which are easily separable by distension with air or water, and by slight maceration. The generality of anatomists conceive it to be of an areolar character, yet it is manifestly contractile; corrugates the scrotum, and doubtless consists of muscular tissue also: Professor Horner,[2] indeed, affirms, that he dissected a subject in January, 1830, in which the fibres were evidently muscular, although interwoven. Beneath the dartos a third coat exists, which is muscular:—it is called *cremaster*

[1] Western Journal of Medicine and Surgery, May, 1841, p. 355.
[2] Special Anat. and Histology, 7th edit., ii. 116, Philad., 1846.

or *tunica erythroïdes;* arises from the lesser oblique muscle of the abdomen; passes through the abdominal ring; aids in the formation of the spermatic cord, and terminates insensibly on the inner surface of the scrotum. It draws the testicle upwards. The areolar substance, that connects the dartos and cremaster with the tunica vaginalis, has been considered by some as an additional coat, and termed *tunica vaginalis communis.* The *tunica vaginalis* or *tunica elytroïdes*, is a serous membrane, enveloping the testicle and lining the scrotum; having, consequently, a scrotal and a testicular portion. We shall see, hereafter, that it is a dependence of the peritoneum, passing before the testicle in its descent, and afterwards becoming separated from any direct communication with the abdomen. The *vas deferens* or excretory duct of the testicle commences at the globus minor of the epididymis, (C, Fig. 359,) itself formed of a convoluted tube. This, when unfolded, according to Monro, measures thirty-two feet. As soon as the vas deferens quits the testicle, it joins the spermatic cord; passes upwards to the abdominal ring; separates from the bloodvessels on entering the abdomen, and descends downwards and inwards to the posterior and inferior part of the bladder, passing between the *bas-fond* of the latter and the ureter. It then converges towards its fellow along the under extremity of the bladder, at the inner margin of the vesicula seminalis of the same side, and ultimately opens into the urethra near the neck of the bladder. (Fig. 356.) At the base of the prostate, it receives a canal from the vesicula, and continues its course to the urethra under the name of *ejaculatory duct.* The vas deferens has two coats, the outer of which is very firm and almost cartilaginous; but its structure is not manifest; the inner thin, and belonging to the class of mucous membranes. The *vesiculæ seminales*, Fig. 356, *v*, and Fig. 362, 4, 4, are considered to be two convoluted tubes,—one on each side,—which are two inches or two inches and a half long, and six or seven lines broad at the fundus, and are situate at the lower fundus of the bladder, between it and the rectum, and behind the prostate gland. At the anterior extremities they approach each other very closely, being separated only by the vasa deferentia. When inflated and dried, they present the appearance of cells; but are generally conceived to be tubes, which, being convoluted, are brought within the compass of the vesiculæ. When dissected and stretched out, they are four or five inches long by about one-fourth of an inch in diameter. M. Amussat,[1] however, denies this arrangement

Fig. 362.

Vertical Section of the Union of Vas Deferens and Vesiculæ Seminales so as to show their Cavities.

1, 1. Vas deferens with thick parietes and narrow cavity. 2, 2. Portion of the same where the cavity is enlarged. 3, 3. Extremities of vas deferens from each side where they join the vesiculæ seminales and ductus ejaculatorius. 4, 4. Vesiculæ seminales distended with air and dried 5, 5. Arteries to the vesiculæ. 6. Portion of the peritoneum covering the posterior part of the vesiculæ. 7. Ejaculatory ducts.

[1] Magendie, Précis, &c., ii. 514.

of the vesiculæ, and affirms, that he has discovered them to be formed of a minute canal of considerable length, variously convoluted, the folds of which are united to each other by cellular filaments, like those of the spermatic vessels. At the anterior part, termed the *neck*, a short canal passes off, which unites at an acute angle with the vas deferens, to form the *ductus ejaculatorius*. Between the openings of the ejaculatory ducts at the lateral and anterior part of the verumontanum, there is often a depression, sometimes of a large size, which is termed *utriculus*, *vesica* seu *vesicula prostatica* and *sinus pocularis*, and has been regarded as the analogue to the uterus in the female.[1] The vesiculæ are formed of two membranes; the more external like that of the vas deferens, and capable of contracting in the act of ejaculation; and an internal mucous lining, of a white, delicate character, a little like that which lines the interior of the gall-bladder. The vesiculæ are manifestly contractile, owing to unstriped muscular fibres in their second coat. They are filled, in the dead body, with an opaque, thick, yellowish fluid, very different in appearance from the sperm ejaculated during life.

The *prostate gland* (Fig. 356, *p*) is an organ of very dense tissue, embracing the neck of the bladder, and penetrated by the urethra, which traverses it much nearer its upper than lower surface. The base is directed backwards; the point forwards, and its inferior surface rests upon the rectum, so that, by passing the finger into the rectum, enlargements of the organ may be detected. The prostate was once universally esteemed glandular, and is still so termed; but it is generally and correctly regarded as an agglomeration of several small follicles, filled by a viscid whitish fluid. These follicles have numerous minute excretory ducts, which open on each side of the caput gallinaginis.

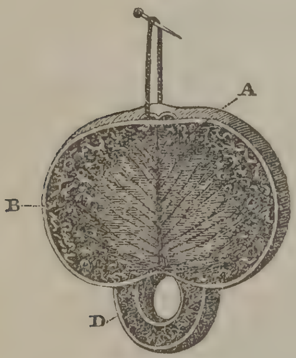
The *glands of Cowper* are two small, oblong bodies; of the size of a pea; of a reddish colour, and somewhat firm tissue. They are situate anterior to the prostate; parallel to each other, and at the sides of the urethra. Each has an excretory duct, which creeps obliquely in the spongy tissue of the bulb, and opens before the verumontanum.

The *male organ* or *penis* consists of the *corpora cavernosa* and *corpus spongiosum;* parts essentially formed of an erectile tissue, and surrounded by a very firm elastic covering, which prevents over-distension, and gives form to the organ. The *corpora cavernosa* constitute the great body of the penis. They are two tubes, which are united and separated by an imperfect partition. Within them a kind of cellular tissue exists, into which blood is poured, so as to cause erection. The posterior extremities of these cavernous tubes are called *crura penis*. These separate in the perineum, each taking hold of the ramus of the pubis; and, at the other extremity, the cavernous bodies terminate in rounded points under the glans penis. The anatomical elements of the internal tissue of the corpora cavernosa are,—ramifications of the *cavernous artery*, which proceeds from the internal pudic; those of a vein bearing the same name; and probably, nerves,—although they

[1] E. H. Weber, Müller's Archiv., s. 421, Jahrgang, 1846.

have not been traced so far. All these elements are supported by filamentous prolongations from the outer dense envelope. A difference of opinion prevails amongst anatomists with regard to the precise arrangement of these prolongations. Some consider them to form cells, or a kind of spongy structure, on the plates of which the ramifications of the cavernous artery and vein and of the nerves terminate, and into which the blood is extravasated. Others conceive, that the internal arrangement consists of a plexus of minute arteries and veins, supported by the plates of the outer membrane, interlacing like the capillary vessels, but with this addition, that in place of the minute veins becoming capillary in the plexus, they are of greater size, forming very extensible dilatations and net-works, and anastomosing freely with each other. If the cavernous artery be injected, the matter first fills the ramifications of the artery, then the venous plexuses of the cavernous bodies, and ultimately returns by the cavernous vein, having produced erection. The same effect is caused still more readily by injecting the cavernous vein. Professor J. Müller, who has investigated the structure of the male organ, discovered two sets of arteries in the organ,

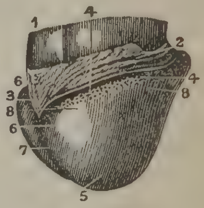
Fig. 363.



Section of the Penis.

A. External membrane or sheath of penis. B. Corpus cavernosum. D. Corpus spongiosum urethræ.

Fig. 364.



Glans Penis injected.

1, 1. Portions of corpora cavernosa. 2. Prepuce turned back. 3. Its frænum. 4, 4. Glandulæ odoriferæ Tysoni. 5. Point of glans. 6. Prominences of glans on each side of frænum. 7. Furrow which separates the sides of the glans. 8. Corona glandis.

differing from each other in size, mode of termination, and uses: the first he calls *rami nutritii*, which are distributed upon the parietes of the veins and throughout the spongy substance, differing in no respect from the nutritive arteries of other parts. The second set he calls *arteriæ helicinæ*. They differ from the nutritive vessels in form, size, and distribution. They are short, and are given off from the larger branches, as well as from the finest twigs of the artery; most of them come off at a right angle, and project into the cavity of the spongy substance, either terminating abruptly or swelling out into a clublike process without again subdividing. Almost all these arteries have this character, that they are bent like a horn, so that the end describes half a circle or somewhat more. These arteries have a great resemblance to the tendrils of the vine, whence their name—*arteriæ helicinæ*. A

minute examination of them, either with the lens or with the microscope, shows, that, although they at all times project into the venous cavities of the corpora cavernosa, as in the subjoined figures, they are

Fig. 365.

Portion of the Erectile Tissue of the Corpus Cavernosum magnified, to show the areolar structure and the distribution of the arteries. (Müller.)

a. A small artery, supported by the larger trabeculæ, and branching out on all sides. *c*. The tendril-like arterial tufts, or helicine arteries of Müller. *d*. The areolar structure formed by the finer trabeculæ.

Fig. 366.

A single Tuft or Helicine Artery projecting into a Vein, highly magnified. (Müller.)

not entirely naked, but are covered by a delicate membrane, which under the microscope appears granular. The views of Müller are embraced by Erdl, Krause, and Hyrtl,[1] but the researches of Valentin[2] and Berres are not in accordance with them. The result of numerous examinations has convinced the former, that the helicine arteries are not peculiar vessels, but merely minute arteries that have been divided or torn; and that the real distribution of the vessels of the corpora cavernosa follows in every respect the most simple laws. The investigations of Müller have led him to infer, that, both in man and the horse, the nerves of the corpora cavernosa are made up of branches proceeding from the organic as well as the animal system, whilst the nerves of animal life alone furnish the nerves of sensation of the penis.

Attached to the corpora cavernosa, and running in the groove beneath them, is a spongy body of similar structure,—*corpus spongiosum urethræ*,—through which the urethra passes. It commences, posteriorly, at the bulb of the urethra,—already described under the Secretion of Urine,—and terminates anteriorly in the *glans*, which is, in no wise, a dependency of the corpora cavernosa, but is separated from them by a portion of their outer membranes; so that erection may take

[1] Lehrbuch der Anatomie des Menschen, s. 505, Prag, 1846.

[2] Müller's Archiv. für Anatomie, u. s. w., cited in Lond. Med. Gazette, June 23, 1838, p. 543; and Valentin, Lehrbuch der Physiologie des Menschen, ii. 841, Braunschweig, 1844.

place in the one, and not simultaneously in the other; and injections into the corpora cavernosa of the one do not pass into those of the other. The glans appears to be the final expansion of the erectile tissue which surrounds the urethra. The posterior circular margin of the glans is called *corona glandis*, and behind this is a depression termed *cervix*, *collum* or *neck*. Several follicles exist here, called *glandulæ odoriferæ Tysoni:* these have always been considered to secrete an unctuous humour called *smegma præputii*, which often accumulates largely, where cleanliness is not attended to. The little white elevations that are found around the corona glandis, have been generally regarded as Tyson's glands. They have, however, been examined by Dr. G. Simon,[1] who affirms, that they are nothing more than small round elevations of cutis, covered by papillæ and epithelium. They consist of fibro-areolar tissue, like that of the rest of the cutis; and the papillæ on them have no peculiar characters. The sole function which he ascribes to them is that of increasing the sensibility of the glans. The only organs, which Dr. Simon could find for the special secretion of the smegma—and these are not constant—are whitish corpuscles lying in or beneath the cutis, which, with the microscope, appear as small roundish sacculi, closed below, opening by a narrow orifice on the surface, and containing a white substance. These are usually situate on or behind the corona glandis, in front of or near the frænum, and sometimes on the anterior surface of the glans. Two or three may be found, and, in a few cases, as many as six.

The penis is covered by the skin, which forms, towards the glans, the *prepuce* or *foreskin*. The areolar tissue which unites it to the organ is lax, and never contains fat. The inner lamina of the prepuce being inserted circularly into the penis, some distance back from the point, the glans can generally be denuded, when the prepuce is drawn back. The under and middle part of the prepuce is attached to the extremity of the glans by a duplicature, called *frænum præputii*, which extends to the orifice of the urethra. The skin is continued over the glans, but it is greatly modified in its structure, being smooth and velvety, highly delicate, sensible, and vascular.

Lastly.—In addition to the *acceleratores urinæ*, *transversus perinei*, *sphincter ani*, and *levator ani* muscles, which we have described as equally concerned in the excretion of urine and semen, the *erector penis* or *ischio-cavernosus* muscle is largely connected with the function of generation. (See Fig. 357.) The genital organs of man are, in reality, merely an apparatus for a glandular secretion, of which the testicle is the gland; the vesiculæ seminales are supposed to be the reservoirs; and the vas deferens and urethra the excretory ducts;—the arrangement which we observe in the penis being for the purpose of conveying the secreted fluid into the parts of the female.

SPERM.

The sperm is secreted by the testicles from the blood of the spermatic artery, by a mechanism, which is no more understood than that of

[1] Müller's Archiv., 1844, Heft 1, cited in Brit. and For. Med. Rev., April, 1845, p. 567.

secretion in general. When formed, it is received into the tubuli seminiferi, and passes along them to the epididymis, vas deferens, and vesiculæ seminales, where it is generally conceived to be deposited, until under venereal excitement it is projected into the urethra. That this is its course is sufficiently evidenced by the arrangement of the excretory ducts, and by the function which it has to fulfil. De Graaf,[1] however, adduces an additional proof. On tying the vas deferens of a dog, the testicle became swollen under excitement, and ultimately the duct gave way between the testicle and ligature. The causes of the progression of the sperm through the ducts are,—the continuity of the secretion by the testicle, and the contraction of the excretory ducts themselves. These are the efficient agencies.

It has been a question with physiologists, whether the secretion of the sperm be constantly taking place—or whether, as the function of generation is accomplished at uncertain intervals, the secretion may not likewise be intermittent. It is impossible to arrive at any positive conclusion on this point. It would seem, however, unnecessary for the secretion to be effected at all times; and it is more probable, that when the vesiculæ seminales are emptied of their contents during coition, a stimulus is given to the testes by the excitement, and they are soon replenished. This, however, becomes more and more difficult in proportion to the number of repetitions of the venereal act, as the secretion takes place at best but slowly. By some, the spermatic and pampiniform plexuses have been regarded as diverticula to the testes during this intermission of action. The sperm passes slowly along the excretory ducts of the testicle, owing partly to the slowness of the secretion, and partly to the arrangement of the ducts, which, as we have seen, are remarkably convoluted, long, and minute. The use of the vesiculæ seminales has been disputed. The majority of physiologists consider them to be reservoirs for the sperm, and to serve the same purpose as the gall-bladder in the case of the bile. Others, however, have supposed, that they secrete a fluid of a peculiar nature, the use of which may probably be to dilute the sperm; whilst others, again, infer, that they are both seminal reservoirs, and secreting organs,—furnishing mucus, or some other fluid, for admixture with the semen. Dr. John Davy[2] found spermatozoids in the fluid of the vesiculæ; but except in two instances no animalcules could be seen in that expressed from the divided substance of the testes. He invariably observed, however, extremely minute, dense spherules, which he conjectured to be ova of spermatozoids.[3] The vesiculæ are manifestly not essential to the function of generation, as they do not exist in all animals; and in several animals in which they do, there is no direct communication between the duct and the vas deferens, which open separately into the urethra. This circumstance, however, with the fact, that they generally contain, after death, a fluid of different appearance and properties from those of the sperm,—with the glandular structure, which their

[1] De Virorum Organ. Gener. Inserv., in Med. Oper. Omn., Amstel., 1705.

[2] Edinb. Med. and Surg. Journ. for July, 1838, p. 12; and Researches, Physiological and Anatomical, Amer. Med. Libr. edit., p. 363, Philad., 1840.

[3] Ibid., p. 373.

coats seem in many instances to possess,—is opposed to the view, that they are simple reservoirs for semen, and favours that which ascribes to them a peculiar secretion. Where this communication between the duct of the vesiculæ and the vas deferens exists, a reflux of the semen and an admixture between the sperm and the fluid secreted by them may take place. It is not improbable, however, as M. Adelon[1] suggests, that all the excretory ducts of the testicle may act as a reservoir; and in the case of animals, in which the vesiculæ are wanting, they must possess this office exclusively. If we are to adopt the description of M. Amussat as an anatomical fact, the vesiculæ themselves are constituted of a convoluted tube, having an arrangement somewhat resembling that which prevails in the excretory ducts of the testes.[2]

That these excretory ducts may serve as reservoirs is proved by the fact, that impregnation is practicable after thorough castration. This has been doubted both as regards animals and man, but there is no question of the fact as respects the former. Dr. Pue, of Baltimore, related to the author unquestionable instances of the kind. In one case, a boar was observed on one side of a hedge striving to get at some sows in heat on the other side. The boar was castrated, and no inconvenience being apprehended, he was turned loose into the field with the sows. In five minutes after the operation, he had intercourse with one of them, and subsequently with others. The first sow brought forth a litter, but none of the others were impregnated. In another case, after a horse had been castrated, it was recollected, that the male organ had not been washed—which, it seems, is looked upon as advisable. To save inconvenience, it was suggested, that the same effect might be produced by putting him to a mare, then in the stable, and in heat. This was done, and, in due time, the mare brought forth a foal, unequivocally the result of this sexual union. Mr. Walton Hamilton,—a great breeder of horses, in Saratoga county, New York,—informed the author's friend, Mr. Nicholas P. Trist, that he, also, had known several instances of impregnation after castration.[3]

It is to be presumed, that the power of procreation can exist for a short time only after the operation; yet a secretion may take place from the lining membrane of the ducts, and vesiculæ, and from the prostate and other follicles;—but this secretion cannot supply the place of sperm. Sir A. Cooper gives the case of a man, who stated to him, that for nearly the first twelve months after complete castration, he had emissions in *coitu*, or the sensation of emissions. Afterwards, he had erections and intercourse at distant intervals, but without the sensation of emission.[4]

It has been asked, how it happens, that the sperm, in its progress along the vas deferens, does not pass directly on into the urethra by the ejaculatory duct, instead of reflowing into the spermatic vesicles where these exist? This, it has been imagined, is owing to the exist-

[1] Physiologie de l'Homme, 2de édit., iv. 15, Paris, 1829.

[2] Magendie, Précis, &c., ii. 348.

[3] See some remarks, by the author, in American Medical Intelligencer, p. 146, July 15 1837; and by Dr. Warrington, Ibid., p. 244, Oct. 1.

[4] Observations on the Structure and Diseases of the Testis, Lond., 1830.

ence of an arrangement at the opening of the ejaculatory duct into the urethra, similar to that which prevails at the termination of the choledoch duct in the duodenum. It is affirmed by some, that the prostate exerts a pressure on the ductus ejaculatorius, and that the opening of the duct into the urethra is smaller than any other part of it; by others, that the ejaculatory ducts are embraced, along with the neck of the bladder, by the levator ani, and consequently, that the sperm finds a readier access into the ducts of the vesiculæ.

Sperm—*sperma*, *semen*, *lac maris*, *male's milk*, *propagatory* or *genital liquor*, *vitale virus*, *vital* or *quickening venom*—is of a white colour, and of a faint smell, which, owing to its peculiar character, has been termed *spermatic*. This smell would seem to be derived from the secretions of the vesiculæ seminales, prostate, and mucous follicles of the urethra, as pure semen taken from the epididymis or vas deferens does not possess it. It is of viscid consistence, a saline, irritating taste, and appears composed of two parts, the one more liquid and transparent, and the other more grumous. In a short time after emission, these two parts unite, and the whole becomes more fluid. When examined chemically, sperm appears to be of an alkaline, and albuminous character. M. Vauquelin[1] analyzed it, and found it to be composed,—in 1000 parts,—of water, 900; animal mucilage, 60; soda, 10; calcareous phosphate, 30. John's analysis[2] accords with this. Berzelius affirms, that it contains the same salts as the blood, along with a peculiar animal matter—*spermatin*. After citing these analyses, M. Raspail[3] observes, that if any thing be capable of humiliating the pride of the chemist, it is assuredly the identity he is condemned to discover amongst substances, which fulfil such different functions. Of late, the sperm of the carp, the cock, and the rabbit has been subjected to repeated and careful analysis by Professor Frerichs of Göttingen; and the following are the published results. *First*. The pure semen presents the appearance of a milky fluid, of a mucous consistence and neutral reaction. A slight alkaline reaction was perceived only once. *Secondly*. The developed spermatozoids consist of binoxide of protein; the same substance, which Mulder has proved to be the principal constituent of the epithelia, as well as of the horny tissues in general. *Thirdly*. The spermatozoids contain about 4 per cent. of a butter-like fat, as well as phosphorus in an unoxidized state, and about 5 per cent. of phosphate of lime. *Fourthly*. The fluid part is a thin solution of mucus, which, in addition to the animal matter, contains chloride of sodium and small quantities of phosphate and sulphate of the alkalies. *Fifthly*. The imperfectly developed spermatozoids are composed of an albuminous substance, the quantity of which diminishes in proportion to the progress of the morphological developement. *Sixthly*. The perfectly developed semen contains no longer any albuminous compound; and, *Seventhly*. The semen in fishes, birds, and the mammalia possesses, essentially, the same chemical composition.

The most important inference deducible from these statements com-

[1] Annales de Chimie, ix. 64.

[2] Chemische Tabellen des Thierreichs, s. 169, Nürnberg, 1814; cited in Burdach's Physiologie, u. s. w. i. 111.

[3] Chimie Organique, p. 386, Paris, 1833.

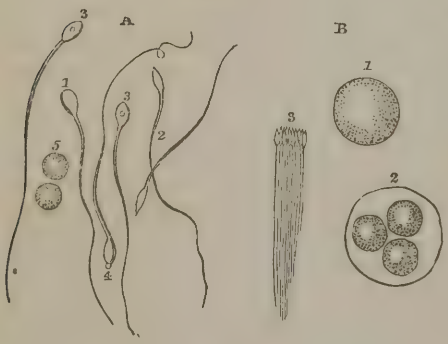
municated by Professor Frerichs to Messrs. Wagner and Leuckardt,[1] is, according to these gentlemen, the fact, that the spermatozoids, in their chemical constitution, belong to the same category as the epithelial cells of the animal body, which, they think, removes every doubt respecting the nature of these formations,—every idea, that is, of their being independent animals. That they are not so appears to the author most probable, but not for the chemical reasons given by these gentlemen, whose conclusion can scarcely, indeed, be regarded in any other light than as a *non sequitur*.

No analysis has been made of the sperm as secreted by the testicle. The fluid examined has been the compound of pure sperm and the secretions of the prostate gland and those of Cowper. The thicker, whitish portion is considered to be the secretion of the testicles;—the more liquid and transparent, the fluids of the accessory glands or follicles.

Some authors have imagined, that a sort of halitus or aura is given off from the sperm, which they have called *aura seminis*, and have considered to be sufficient for fecundation. The fallacy of this view will be exhibited hereafter.

By the microscope, numerous minute bodies, already referred to, are seen in the sperm, termed *seminal animalcules*, *spermatozoa*, *zoospermes*, *spermatozoids* or *seminal filaments*—which have generally been conceived important agents in generation. By careful examination, Wagner[2] discovered other minute, round, granulated bodies which may almost always be detected; and are much less numerous than the spermatozoids. These bodies he distinguishes by the name *seminal granules*, *granula seminis*. Both elements of the sperm are suspended in a small quantity of fluid perfectly homogeneous, transparent and clear as water. "Pure semen, therefore, in its most perfect state, consists principally of *seminal animalcules* and *seminal granules*, both of which are enveloped in a small quantity of fluid." This fluid Wagner called *liquor seminis;* and he suggested,[3] in connexion with the discoveries of Schwann and Schleiden, referred to at page 202 of this volume, whether, in

Fig. 367.



Spermatozoa from Man, and their developement. (Wagner.)

A. Spermatozoa from the semen of the vas deferens. 1 to 4. Show their variety of character. 5. Seminal granules.—B. Contents of the semen of the testis. 1. Large round corpuscle or cell. 2. A cell containing three roundish granular bodies, from which the spermatozoa are developed. 3. A fasciculus of spermatozoa, as they are seen grouped together in the testis.

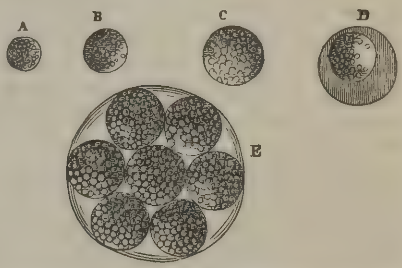
[1] Art. Semen, Cyclop. of Anat. and Physiol., Pt. xxxiv. p. 506, January, 1849.

[2] Elements of Physiology, translated from the German, by Robert Willis, M. D., part i. p. 4, Lond., 1841: see, also, Mandl, Manuel d'Anatomie Générale, p. 494, Paris, 1843.

[3] Op. cit., p. 27.

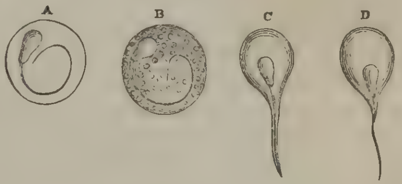
the developement of the spermatozoids, the liquor seminis may not be regarded as a matrix, (Zellenkeimstoff, *cytoblastema*, Schwann,) in which the granular nuclei are developed as *cytoblasts*, which again put forth their covering or cyst as a cellular wall. The finely granular contents would then have to be considered as the *cell-fluid*. The cytoblasts disappear as soon as the spermatozoids are evolved in their contents; and the cells burst and cast out the fancied animalcules, as the cells of the algæ scatter abroad their sporules. More recently, Wagner, in conjunction with Leuckardt, has published the results of his farther observations and of those of others on this matter. Among the mammalia, they affirm, the developement of spermatozoids takes place in the interior of vesicle-shaped globules, which fill up the minute ducts of the testicles in great quantity. Most of these vesicles, "vesicles of evolution," are free within the ducts, as represented in the marginal figures, A, B, C; and are frequently surrounded by a membrane, either singly, as in D, or in numbers of from three to seven, E; and, according to Kölliker, one cyst may contain as many as twenty. All these cells of evolution or developement are formed within other cells; and it is often difficult to determine, whether an individual cell or vesicle is destined for the production of other cells —daughter cells—or immediately for the formation of a spermatozoid. Wherever free vesicles of developement are found, they have—in the opinion of Wagner and Leuckardt[1]—been produced in the interior of other cellular formations, and have been set free by their dissolution. Each spermatozoid would seem to be produced in a separate cyst, and where many of these are seen in one cyst, it is owing to the different vesicles having burst and discharged their spermatozoids into the external cyst. The number of enclosed spermatozoids will thus be an index of the number of vesicles of developement. A, B, C, D, Fig. 369, exhibit the mode in which the spermatozoid lies in the vesicle of developement; and in which it is occasionally seen projecting from it.

Fig. 368.



Developing Vesicles of Spermatozoids from the Testicle of the Dog.

Fig. 369.



Spermatozoid of the Dog in the Interior of the Vesicle of Developement.

Great difference of sentiment has existed in regard to the nature of those bodies. M. Virey[2] conceives, that as the pollen of vegetables is

[1] Op. cit., p. 477.

[2] Art. Génération, in Dict. des Sciences Médicales; and Philosophie d'Histoire Naturelle, Paris, 1835.

a collection of small capsules, containing within them the true fecundating principle, which is of extreme subtilty, the pretended spermatic animalcules are tubes containing the true sperm, and the motion we observe in them is owing to the rupture of the tubes; whilst M. Raspail[1] is led to think, that they are mere shreds, (*lambeaux*,) of the tissues of the generative organs, ejaculated with the sperm, which describe involuntary movements by virtue of the property they possess of *aspiring* and *expiring*. In confirmation of this view, he states, that if we open an ovary of the mussel, we may observe alongside the large ovules myriads of moving shreds, whose form and size are infinitely varied, and which possess nothing resembling regular organization. They bear evident marks of laceration. These shreds, he conceives, may affect greater regularity in certain classes of animals of a more elevated order; but, he concludes, that howsoever this may be, the spermatic animalcules, which have hitherto been classed amongst those *incertæ sedis*, may be provisionally placed in the genus *cercaria*,—that is, amongst infusory, agastric animals having a kind of tail,—which M. Raspail considers the simplest of animated beings, and to live only by "aspiration and expiration." Wagner also remarks, that the expression *cercaria seminis*, applied to spermatozoids, can only be a collective title, and that the manifold forms of spermatozoids, which he has found in the seminal fluid of a great number of animals, must be viewed in the light of so many different species. Ehrenberg refers them to the haustellate entozoa.

The author has repeatedly examined the sperm with microscopes of high magnifying power, but without being able to satisfy himself, that the minute caudate bodies, contained in it, are animalcular. Sir Everard Home and Mr. Bauer[2] were equally unsuccessful, and they were led to conclude, that the appearance of living animalcules in the semen is not real, but the effect of a microscopic deception. Wagner[3] formerly considered, that they are essential elements of the seminal fluid, and bear a specific relation to the generative act, and that they are thus far comparable to the blood-globules; which present themselves in the same manner, as essential typically organized constituents of the blood amid the liquor sanguinis, just as the spermatozoids present themselves amid the liquor seminis. The question of the animality of these spermatozoids he considered to be undetermined, as their internal organization had not been detected. In the appendix, however, to the translation of his work, Dr. Willis[4] remarks, that in the examination of the spermatozoids of the bear, Valentin[5] had settled the question of the organization, and consequently true animal nature, of the seminal animalcule; but the matter was not determined by this statement, nor by the categorical declaration of M. Pouchet,[6] that "every mode of investigation presented to the human mind appears to speak in favour of the animality of the spermatozoids. Inward feeling (*le sens interne*), observation, experiment, and reflection, unite in

[1] Op. citat., p. 389.
[2] Lect. on Comp. Anat., v. 337, Lond., 1828. [3] Op. citat., p. 34.
[4] Ibid., p. 228. [5] Nov. Act. Acad. C. L. Natur. Curios., vol. xi. 1839.
[6] Théorie Positive de l'Ovulation Spontanée, et de la Fécondation, &c., p. 363, Paris, 1847.

expressing, that they can be nothing else than animals." On the other hand, M. Donné,[1] like M. Raspail, regards them as resulting from a kind of desquamation of the parietes of the seminiferous tubes; whilst Carpenter,[2] Dujardin,[3] and others consider, that there is little reason to regard them as independent animalcules. The former esteems them to be bodies having an inherent power of motion, not exceeding in their activity ciliated epithelium cells, and even blood corpuscles; and he thinks there is no evidence, that their function is any higher than that of the pollen-tube of plants, which conveys into the ovulum the germ of the first cells of the embryo. The whole of this subject has been recently re-examined by Wagner in connexion with Leuckardt; and in an able view by these gentlemen,[4] of the morphology and developement of the spermatozoids, we have the following remarks:—"At the period when the spermatozoa were still considered as individual animated creatures, it was natural, that those qualities should be sought for, which distinguish animals generally; and it was frequently asserted, that the distinct traces of an internal organization had been found in them. Even Leeuwenhoek,[5] the oldest observer of these structures, describes in the body of the spermatozoa of the ram and of the rabbit indications, which were subsequently interpreted by Ehrenberg[6] and Valentin[7] to be intestines, stomachic vesicles, and even generative organs. Other histologists, for instance, Schwann and Henle, thought themselves justified in calling a dark spot, which shows itself occasionally on the body of the spermatozoon in man, but which is decidedly a mere accidental formation, as a suctorial cavity. But all these statements are now no longer believed in, as our present knowledge of the developement of these formations has entirely removed the idea of their parasitic nature. Indeed, the subject requires no further refutation, as an unprejudiced observation proves that the spermatozoa are everywhere void of a special organization, and consist of a uniform homogeneous substance, which exhibits, when examined by the microscope, a yellow amber-like glitter. The above-mentioned investigators have by this time undoubtedly seen their error."

The view, that they are reproductive particles, but not animalcules, appears to the author to be the most in accordance with the phenomena.

The presence of spermatozoids, whole or broken in fragments, may aid in detecting nocturnal emissions, and be of assistance in cases of alleged rape. It would seem, however, that they are not found solely in the sperm: for Mr. Liston and Mr. Lloyd,[8] of St. Bartholemew's Hospital, London, stated to the Medico-Chirurgical Society, that in cases of common hydrocele, in which he examined microscopically the fluid withdrawn by tapping, he found a great number of them. He

[1] Cours de Microscopie, p. 176, Paris, 1844.
[2] Human Physiology, § 733, Lond., 1842.
[3] Annales des Sciences Natur. Zoologie, viii. 291; and Manuel de l'Observateur au Microscope, p. 96, Paris, 1843.
[4] Art. Semen, in Cyclop. of Anat. and Physiology, part xxxiv. p. 502, Jan., 1849.
[5] Opera, iv. 168, 284.
[6] Infusorienstbiercben, s. 465.
[7] Nov.-Act. Acad. Leopold, xix. 239.
[8] Provincial Medical Journal, cited in Medical Examiner, July 22, 1843, p. 168.

counted forty in one drop. Some were observed to retain their power of motion for three hours after the fluid had been withdrawn. In the fluid of many other cases of hydrocele, Mr. Lloyd was unable to detect them. Since these remarks were made, however, by Mr. Lloyd, they have been observed repeatedly in the fluid of common hydrocele of the tunica vaginalis testis, and in encysted hydroceles.[1] This may be owing to the rupture of a seminal duct; but Mr. Paget[2] considers, that the most probable explanation of their occurrence in the fluid of cysts connected with the testicle seems to be, that certain cysts, seated near the organ which naturally secretes the materials for semen, may possess the power of forming a similar fluid. It must be borne in mind, however, as before remarked, that bodies resembling spermatozoids were found by M. Donné in the nasal mucus.

The agency of the sperm in fecundation will be considered hereafter.

The sperm being the great vivifying agent,—the medium by which life is communicated from generation to generation,—it has been looked upon as one of the most—if not the most—important of animal fluids; and hence it is regarded, by some physiologists, as formed of the most animalized materials, or of those that constitute the most elevated part of the new being—the nervous system. The quantity of sperm secreted cannot be estimated. It varies according to the individual, and to his extent of voluptuous excitement, as well as to the degree of previous indulgence in venereal pleasures. Where the demand is frequent, the supply is larger; although when the act is repeatedly performed, the absolute quantity at each copulation may be less.[3]

b. *Genital Organs of the Female.*

The genital organs of the male effect fewer functions than those of the female. They are inservient to copulation and fecundation only. Those of the female,—in addition to parts, which fulfil these offices,—comprise others for gestation and lactation.

The soft and prominent covering to the symphysis pubis—which is formed by the common integument, elevated by fat, and, at the age of puberty, covered by hair, formerly termed *tressoria*—is called *mons veneris.* The absence of this hair has, by the vulgar, been esteemed a matter of reproach; and it was formerly the custom, when a female had been detected a third time in incontinent practices, in the vicinity of the Superior Courts of Westminster, to punish the offence by cutting off the tressoria[4] in open court. Occasionally its growth is excessive. Below this are the *labia pudendi* or *labia majora*, which are two large,

[1] Medico-Chirurgical Transactions, vol. xxvii., Art. 25, London, 1844; Dr. R. L. Macdonnell, British American Journal of Medicine, Montreal, 1849; and Mr. Curling, Edinb. Monthly Journal of Med. Science, May, 1848; and Art. Testicle, in Cyclop. of Anat. and Physiol., Pt. xxxviii. p. 998, Feb., 1850.

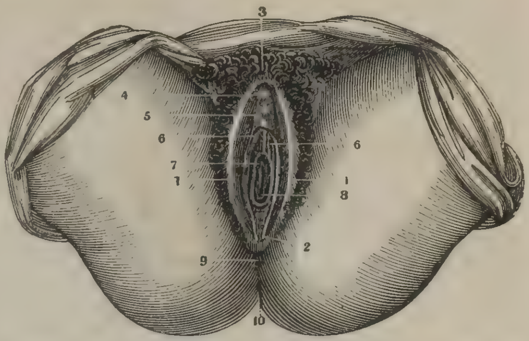
[2] Brit. and For. Med. Rev., January, 1844, p. 270.

[3] Theophrastus, Pliny, and Athenæus assert, that with the help of a certain herb, an Indian prince was able to copulate seventy times in twenty-four hours!—Theophr. l. c. v., Plin. l. xxvi. c. 9, and Athenæus, l. i. c. 12. See, also, Art. Cas rares, in Dict. des Sciences Médicales.

[4] Chitty's Practical Treatise on Medical Jurisprudence, part i. p. 390, American edit., Philad., 1836.

soft lips, formed by a duplicature of the common integument, with adipose matter interposed. The inner surface is smooth, and studded with sebaceous follicles. The labia commence at the symphysis pubis, descend to the *perinæum*, which is the portion of integument, about an inch and a half in length, between the posterior commissure of the labia and the anus. This commissure is called *frænum labiorum frænulum perinei* or *fourchette*. The opening between the labia is the *vulva* or *fossa magna*. At the upper junction of the labia and within them, a small organ exists, called *clitoris* or *superlabia*, which greatly resembles the penis. It is formed of corpora cavernosa, and is terminated anteriorly by the *glans*, which is covered by a prepuce consisting of a prolongation of the mucous membrane of the vagina. Unlike the penis, however, it has no corpus spongiosum or urethra attached to it; but is capable of being made erect by a mechanism similar to that which exists in the penis; and it has two erector muscles, the *erectores clitoridis*,—similar to the erectores penis. Anciently, if a female was detected a fourth time in incontinence in the vicinity of the Superior Courts of Westminster, the clitoris was amputated in open court.[1] Extending from the prepuce of the clitoris, and within the labia majora, are the *labia minora* or *nymphæ*, the organization of which is similar to that of the labia majora. They gradually enlarge as they pass downwards, and disappear when they reach the orifice of the vagina.

Fig. 370.



External Organs of Generation in the Unmarried Female—the Vulva being partially opened.

1, 1. Labia majora. 2. Fourchette. 3. Mons veneris. 4. Præputium clitoridis around glans clitoridis. 5. Vestibulum. 6. Nymphæ. 7. Meatus urinarius. 8. Hymen, open in its central portion and surrounding inferior extremity of the vagina. 9. Perineum. 10. Anus.

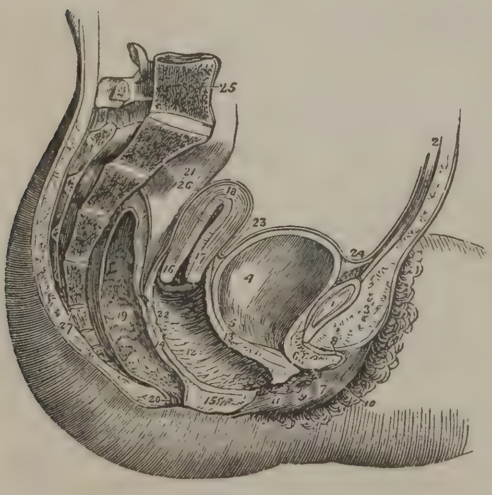
A singular variety is observed in the organization of those parts amongst the Bosjesmen or Bushmen, a tribe to whose peculiarities of organization we have already had occasion to refer. Discordance has, however, prevailed regarding the precise nature of this peculiarity,—some describing it as existing in the labia; others in the nymphæ, and others again, in a peculiar organization; some, again, deeming it natural, others artificial. Dr. Somerville,[2] who had numerous opportunities for observation and dissection, asserts, that the mons veneris is less prominent than in the European, and is either destitute of hair, or thinly covered by a small quantity of a soft, woolly nature; that the labia are very small, so that they seem at times to be almost wanting;

[1] Chitty, op. cit., Part i. p. 391, Amer. edit., Philad., 1836.
[2] Medico-Chirurgical Transactions, vii. 157.

that the loose, pendulous, and rugous growth, which hangs from the pudendum, is a double fold; and that it is proved to be the nymphæ, by the situation of the clitoris at the commissure of the folds, as well as by all other circumstances; and that they sometimes reach five inches below the margin of the labia: Le Vaillant[1] says nine inches. Cuvier[2] examined the Hottentot Venus, and found her to agree well with the account of Dr. Somerville. The labia were very small; and a single prominence descended between them from the upper part. It divided into two lateral portions, which passed along the sides of the vagina to the inferior angle of the labia. The whole length was about four inches. When she was examined naked by the French *Savans*, this formation was not observed. She kept the *tablier*, *ventrale cutaneum*, or, as it is termed by the Germans, S c h ü r z e ("apron,") carefully concealed, either between her thighs, or yet more deeply; and it was not known, until after her death, that she possessed it. Both Sir John Barrow[3] and Dr. Somerville deny, that the peculiarity is artificially excited.

In warm climates, the nymphæ are often greatly and inconveniently elongated, and amongst the Egyptians and other African tribes, it has been the custom to extirpate them, or diminish their size. This is what is meant by *circumcision* in the female.

Fig. 371.



Side View of Viscera of Female Pelvis.

1. Symphysis pubis. 2. Abdominal parietes. 3. Fat forming the mons veneris. 4. Bladder. 5. Entrance of left ureter. 6. Canal of urethra. 7. Meatus urinarius. 8. Clitoris and its prepuce. 9. Left nympha. 10. Left labium majus. 11. Orifice of vagina. 12. Its canal and transverse rugæ. 13. Vesico-vaginal septum. 14. Vagino-rectal septum. 15. Section of perineum. 16. Os uteri. 17. Cervix uteri. 18. Fundus uteri. 19. Rectum. 20. Anus. 21. Upper portion of rectum. 22. Recto-uterine fold of peritoneum. 23. Utero-vesical reflection of peritoneum. 24. Peritoneum reflected on the bladder from abdominal parietes. 25. Last lumbar vertebræ. 26. Sacrum. 27. Coccyx.

The *vagina* is a canal, which extends between the vulva and uterus, the neck of which it embraces. It is sometimes called *vulvo-uterine canal*, and is from four to six inches long, and an inch and a half, or two inches, in diameter. It is situate in the pelvis, between the bladder before, and the rectum behind; is slightly curved, with the concavity forwards, and narrower at the middle than at the extremities. Its inner surface has numerous—chiefly transverse—rugæ, which become less in the

[1] Voyage dans l'Intérieur d'Afrique, p. 371.

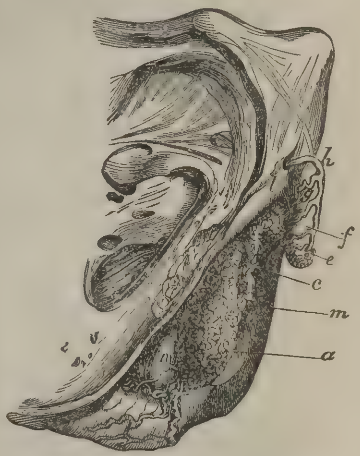
[2] Mémoir. du Museum, iii. 266; and Broc, Essai sur les Races Humaines, p. 87, Paris, 1835.

[3] Travels into the interior of Southern Africa, p. 279; also, Lawrence's Lectures on Comparative Anatomy, Physiology, Zoology, &c., 9th edit, p. 289, Lond., 1844.

progress of age, after repeated acts of copulation, and especially after accouchement. It is composed of an internal mucous membrane, supplied with numerous follicles, of a dense areolar membrane; and, between these, a layer of erectile tissue, which is thicker near the vulva; but is, by some, said to extend even as far as the uterus. It is termed the *corpus spongiosum vaginæ.* It is chiefly situate around the anterior extremity of the vagina, below the clitoris, and at the base of the nymphæ; and the veins of which it is constituted are called *plexus retiformis.* The upper portion of the vagina, to a small extent, is covered by peritoneum. The *sphincter* or *constrictor vaginæ muscle* surrounds the orifice of the vagina, and covers the plexus retiformis. It is about an inch and a quarter wide, and ordinarily about six inches in length; arises from the body of the clitoris, and passes backwards and downwards, to be inserted into the dense, white substance in the centre of the perineum, which is common to the transversi perinei muscles, and the anterior point of the sphincter ani.

Near the external aperture of the vagina is the *hymen* or *virginal* or *vaginal valve*, which is a more or less extensive, membranous duplicature, of variable shape, formed by the mucous membrane of the vulva, where it enters the vagina, so that it closes the canal more or less completely. It is generally very thin, and easily lacerable: but is sometimes extremely firm, so as to prevent penetration. It is usually of a semilunar shape; sometimes oval from right to left, or almost circular, with an aperture in the middle; whilst, occasionally, it is entirely imperforate, and of course prevents the issue of the menstrual flux. It is easily destroyed by mechanical violence of any kind, as by strongly rubbing the sexual organs of infants by coarse cloths, and by ulcerations of the part; hence its absence is not an absolute proof of the loss of virginity, as it was of old regarded by the Hebrews, nor is its presence a positive evidence of continence. Individuals have conceived, in whom the aperture of the hymen has been so small as to prevent penetration. Its general semilunar or crescentic shape has been considered to explain the origin of the symbol of the *crescent* assigned to Diana, the goddess of chastity. Around the part of the vagina where the hymen was situate, small, reddish, flattened, or rounded tubercles—*carunculæ myrtiformes* seu *hymenales*—afterwards exist, which are of various sizes; and are formed, according to the general opinion, by the

Fig. 372.

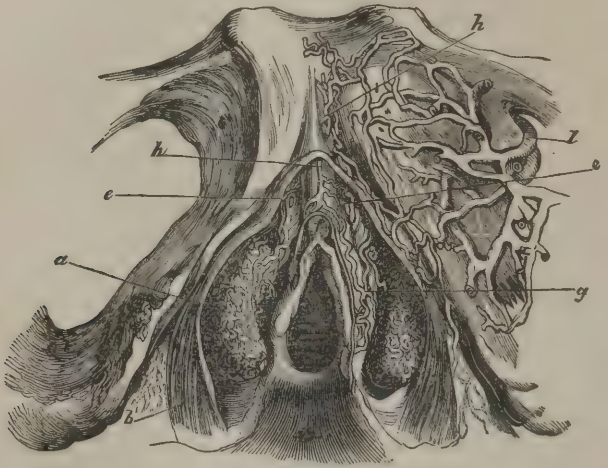


Lateral View of the Erectile Structures of the External Organs of Generation in the Female, the Skin and Mucous Membrane being removed. (Kobelt.)

a. Bulbus vestibuli. *c*. Plexus of veins named pars intermedia. *e*. Glans of the clitoris. *f*. Body of the clitoris. *h*. Dorsal vein. *l*. Right crus of clitoris. *m*. Vulva. *n*. Right gland of Bartholine.

remains of the hymen. MM. Béclard and J. Cloquet[1] consider them to be folds of mucous membrane. Their number varies from two to five, or six.

Fig. 373.



Front View of the Erectile Structures of the External Organs of Generation in the Female.

a. Bulbus vestibuli. *b*. Sphincter vaginæ muscle. *e*, *e*. Venous plexus, or pars intermedia. *f*. Glans of the clitoris. *g*. Connecting veins. *h*. Dorsal vein of the clitoris. *k*. Veins going beneath pubes. *l*. The obturator vein.

At either side of the entrance of the vagina, beneath the integument covering its inferior part, as well as the superficial perineal fascia, and

Fig. 374.

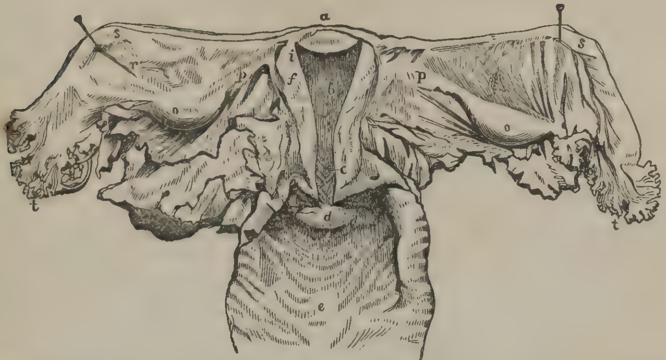
Anterior View of the Uterus and Appendages.

a. Fundus, *b*, body, and *c*, cervix or neck of the uterus. *e*. Front of the upper part of the vagina. *n*, *n*. Round ligaments of the uterus. *r*, *r*. Broad ligaments. *s*, *s*. Fallopian tubes. *t*. Fimbriated extremity. *u*. Ostium abdominale. The position of the ovaries is shown through the broad ligaments; and also the cut edge of the peritoneum, along the lower border of the broad ligaments and across the uterus.

[1] Dictionnaire de Médecine, &c., art. Caroncule, Paris, 1821.

the constrictor vaginæ muscle, are situate the *glands of Duverney*, or *of Bartholin*. The space they occupy lies between the lower end of

Fig. 375.

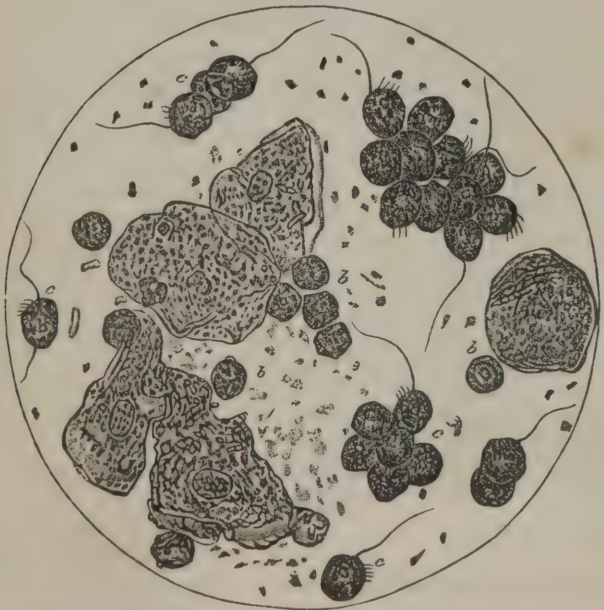


Posterior View of the Uterus and its Appendages: the Cavity of the Uterus being shown by the removal of its Posterior Wall; and the Vagina being laid open.

a. Fundus, *b*, body, and *c*, cervix of the uterus, laid open. The arbor vitæ is shown in the cervix. *d*. The os uteri externum, laid open. *e*. The interior of the upper part of the vagina. *f*. Section of the walls of the uterus. *i*. Opening into Fallopian tube. *o*. Ovary. *p*. Ligament of ovary. *r*. Broad ligament. *s*. Fallopian tube. *t*. Fimbriated extremity.

the vagina, the ascending ramus of the ischium, the crus clitoridis, and the erector clitoridis muscle. The excretory duct is at the anterior edge

Fig. 376.



Vaginal Mucus containing Trichomonads, magnified 400 diameters.

b, *b*, *b*. Purulent globules. *c*, *c*, *c*, *c*. Trichomonads. (Donné.)

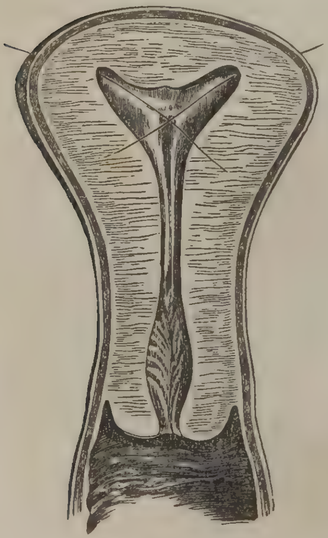
of the superior part of the gland, and runs beneath the constrictor vaginæ, horizontally forwards and inwards, to the inner face of the nympha, opening in front of the carunculæ myrtiformes in the midst of a number of small mucous follicles. These glands secrete a thick, tenacious, grayish-white fluid, which is emitted in considerable quantity towards the termination of sexual intercourse, and—it has been suggested—through the spasmodic contraction of the constrictor vaginæ muscle under which they lie.

When proper attention to cleanliness is not paid, so that the secretion from the mucous membrane of the vagina is no longer healthy, an animalcule (?)—the *trichomonas vaginalis*—has been detected in it by M. Donné;[1] with occasionally small vibriones, which can only be seen when magnified three or four hundred times. (Fig. 376.) Gluge, Valentin, Siebold and Vogel,[2] however, are of opinion, that this imaginary infusorium is not an animal, but ciliated epithelium separated from the uterus.

The vagina is at times double. Three such cases have been recorded by Professor Meigs.[3]

The *uterus* is a hollow organ for the reception of the fœtus, and its retention during gestation. It is situate in the pelvis, between the bladder—which is before, and the rectum behind, and below the convolutions of the small intestines. Fig. 371 gives a lateral view of their relative situation. It is of a conoidal shape, flattened on the anterior and posterior surfaces; rounded at the base, which is above, and truncated at its apex, which is beneath. It is of small size; its length being only about two and a half inches; breadth one and a half inch at the base, and ten lines at the neck; thickness about an inch. It is divided into the *fundus*, *body*, and *cervix* or *neck*. The fundus is the upper part of the organ above the insertion of the Fallopian tubes. The body is the part between the insertion of the tubes and the neck; and the neck is the lowest and narrowest portion, which projects and opens into the vagina. At each of the two superior angles are—the opening of the Fallopian tube, the attachment of the ligament of the ovary, and that of the round ligament. The inferior angle is formed by the neck, which projects into the vagina to the distance of four or five lines, and terminates by a cleft, situate crosswise, called *os tincæ*, *os uteri* or *vaginal orifice of the uterus*. The aperture is bounded by

Fig. 377.



Section of Uterus.

[1] Cours de Microscopie, p. 157, Paris, 1844; and Atlas, Paris, 1845.

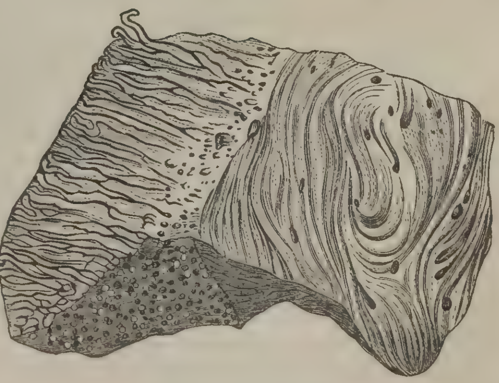
[2] The Pathological Anatomy of the Human Body, by Julius Vogel, translated, &c., by G. E. Day, p. 440, Lond., 1847.

[3] Medical Examiner for December, 1846, p. 703.

two lips, which are smooth and rounded in those that have not had children; jagged and rugous in those who are mothers,—the anterior lip being somewhat thicker than the posterior. It is from three to five lines long, and is generally more or less open, especially in those who have had children. The internal cavity of the uterus is very small in proportion to the bulk of the organ, owing to the thickness of the parietes, which almost touch internally. It is divided into the cavity of the body, and that of the neck. (Fig. 377.) The former is triangular. The tubes open at its upper angles. The second cavity is more long than broad; is broader at the middle than at either end; and at the upper part where it communicates with the cavity of the body of the uterus an opening exists, called *internal orifice* of the uterus; the *external orifice* being the os uteri. The inner surface has several transverse rugæ, which are not very prominent. It is covered by fine villi, and the orifices of several mucous follicles are visible.

The precise organization of the uterus has been a topic of interesting inquiry amongst anatomists. It is usually considered to be formed of two parts, a mucous membrane internally, and the proper tissue of the uterus, which constitutes the principal part of the substance. The mucous membrane has been esteemed a prolongation of that which lines the vagina. It is very thin; of a red hue in the cavity of the body of the organ; white in that of the neck. Chaussier, Ribes, and Madame Boivin, however, deny its existence. Chaussier asserts, that having macerated the uterus, and a part of the vagina, in water, vinegar, and alkaline solutions; and having subjected them to continued ebullition, he always observed the mucous membrane of the vagina stop at the edge of the os uteri; and Madame Boivin,—a well-known French authoress on obstetrics, who has attended carefully to the anatomy of those organs during pregnancy,—says, that the mucous membrane of the vagina terminates by small expansible folds, and by a kind of prepuce, under the anterior lip of the os uteri. In their view, the inner surface of the uterus is formed of the same tissue as the rest of it. The epithelium of the vagina differs, however, from that of the uterus. It is columnar and ciliated as far down as the middle of the cervix uteri, below which it becomes tesselated or squamous, like that of the vagina. When examined with a lens, the mucous membrane is found to be marked over with minute dots, which are the orifices of numerous sim-

Fig. 378.



Section of the Paries of the Uterus magnified three diameters. (Coste.)

The right hand portion is the fibrous structure of the uterus; the left hand the lining membrane and tubular glands. The arrangement of the vessels accompanying these is shown.

ple tubular glands; some of these are branched and others slightly twisted into a coil. They can be seen in the virgin uterus; but become enlarged on impregnation. The proper tissue of the organ is dense, compact, not easily cut, and somewhat resembles cartilage in colour, resistance, and elasticity. It is a whitish, homogeneous substance, penetrated by numerous minute vessels. In the unimpregnated state, the fibres, which enter into the composition of the tissue, appear ligamentous, and pass in every direction, but so as to permit the uterus to be more readily lacerated from the circumference to the centre than in any other direction. The precise character of the tissue has been a matter of contention amongst anatomists. The microscope shows it to be composed of muscular fibres of the unstriped variety, interlacing with each other, but disposed in bands and layers, intermixed with much fibro-areolar tissue, a large number of bloodvessels and lymphatics, and a few nerves. The arrangement of the muscular fibres is best studied at an advanced period of utero-gestation. Besides the usual organic constituents, the uterus has arteries, veins, lymphatics, and nerves. The arteries proceed from two sources;—the spermatic, which are chiefly distributed to the fundus of the organ, and towards the part where the Fallopian tubes terminate; and the hypogastric, which are sent especially to the body and neck. Their principal branches are readily seen under the peritoneum, which covers the organ; they are very tortuous; frequently anastomose, and their ramifications are lost in the tissue of the viscus, and on its inner surface. The veins empty themselves partly into the spermatic, and partly into the hypogastric. They are even more tortuous than the arteries; and, during pregnancy, dilate and form what have been termed *uterine sinuses*. The nerves are derived partly from the great sympathetic, and partly from the sacral pairs. The arrangement of the uterine nerves has given rise to much difference of sentiment. Whilst Dr. Lee[1] considers that the uterus is most copiously supplied with them; others—as Mr. Beck[2] and Dr. Sharpey[3]—have supposed, that he mistook for nerves other structures; and that the number of uterine nerves is by no means great.

The uterus is sometimes absent.[4]

The appendages of the uterus are:—1. The *ligamenta lata* or *broad ligaments*, which are formed by the peritoneum. This membrane is reflected over the anterior and posterior surfaces and over the fundus of the uterus; and the lateral duplicatures of it form a broad expansion, and envelope the Fallopian tubes and ovaria. These expansions are the broad ligaments. (See Figs. 374 and 375.) 2. The *anterior* and *posterior ligaments*, which are four in number and are formed by the

[1] The Anatomy of the Nerves of the Uterus, Lond., 1841; Philosophical Transactions for 1842; and Lectures on the Theory and Practice of Midwifery, Amer. edit., p. 108, Philad., 1844; see, also, W. Tyler Smith, Parturition, and the Principles and Practice of Obstetrics, p. 79, Philad., 1849.

[2] Philosophical Transactions, part 2, for 1846.

[3] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit., by Dr. Leidy, ii. 356, Philad., 1849.

[4] For such cases, see Dr. Chew, Amer. Journ. Med. Sciences, May, 1840, p. 39; also, Dr. Meigs, translation of Colombat de l'Isère on Diseases of Females, p. 119, Philad., 1845.

peritoneum. Two of these pass from the uterus to the bladder,—the *anterior;* and two between the rectum and uterus—the *posterior.* 3. The *ligamenta rotunda* or *round ligaments*, (Fig. 374,) which are about the size of a goose-quill, arise from the superior angles of the fundus uteri, and, proceeding obliquely downwards and outwards, pass out through the abdominal rings to be lost in the areolar tissue of the groins. They are whitish, somewhat dense cords, formed by a collection of tortuous veins and lymphatics, nerves, and longitudinal fibres, which were, at one time, believed to be muscular, but are now generally considered to consist of condensed areolar tissue. 4. The *Fallopian* or *uterine tubes;* two conical, tortuous canals, four or five inches in length; situate in the same broad ligaments that contain the ovaries, and extending from the superior angles of the uterus as far as the lateral parts of the brim of the pelvis. (Figs. 374, 375, and 380.) The uterine extremity of the tube (Figs. 375 and 380) is extremely small, and opens into the uterus by an aperture so minute as scarcely to admit a hog's bristle. The other extremity is called *pavilion.* It is trumpet-shaped, fringed, and commonly inclined towards the ovary, to which it is attached by one of its longest fimbriæ. This fringed portion is called *corpus fimbriatum* or *morsus diaboli.* The Fallopian tubes, consequently, open at one end into the cavity of the uterus, and at the other, through the peritoneum into the cavity of the abdomen. They are covered externally by the broad ligament or peritoneum; are lined internally by a mucous membrane, which is soft, villous, and has many longitudinal folds; and between these coats is a thick, dense, whitish membrane, which is possessed of contractility; although muscular fibres cannot be detected in it. Santorini asserts that in robust females the middle membrane of the tubes has two mus-

Fig. 379.

Nerves of the Uterus. (R. Lee.)

Fig. 380.

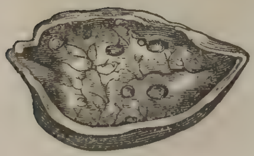
Fallopian Tube.

cular layers; an external, the fibres of which are longitudinal; and an internal, whose fibres are circular.

M. Raciborski,[1] in a memoir read to the *Académie Royale des Sciences* of Paris, states it to be a general rule, that the extremities of the Fallopian tube in domestic animals are so placed during the act of fecundation as to envelope the entire ovary, either directly by means of the open trumpet-shaped extremity, or indirectly by the aid of the fimbriated extremity. In women, however, the fimbriated extremity embraces but a small portion of the ovary; and he thinks, that this anatomical peculiarity is the cause of extra-uterine conception being so much more common in them than in domestic animals. In the latter, indeed, it is very rare.

The *ovaries* (Figs. 375 and 381) are two ovoid bodies, of a pale red colour; rugous, and nearly of the size of the testes of the male. They are situate in the cavity of the pelvis, and are contained in the posterior fold of the broad ligaments of the uterus. At one time they were conceived to be glandular, and were called the female testes; but as soon as the notion prevailed that they contained ova, the term *ovary* or *egg vessel* was given to them. The external extremity of the ovary has attached to it one of the principal fimbriæ of the Fallopian tube. The inner extremity has a small fibro-vascular cord inserted into it; this passes to the uterus, to which it is attached behind the insertion of the Fallopian tube; and a little lower. It is called *ligament of the ovary*, and is in the posterior ala of the broad ligament. It is solid, and has no canal. The surface of the ovary has many round prominences, and the peritoneum—forming the *indusium*—envelopes the whole of it, except at the part where the ovary adheres to the broad ligament. The precise nature of its parenchyma or *stroma* is not determined. When torn or divided longitudinally, as in Fig. 381, it appears to be constituted of a cellulo-vascular tissue. In this, there are spherical vesicles—*ovula Graafiana*, *folliculi Graafiani*, *Follicles de De Graaf*, *ovi-capsules* or *ovisacs*. Roederer[2] asserts, that he found in the ovary of one woman thirty, in that of another about fifty. These are filled with an albuminous fluid, which is colourless or yellowish, and may be readily seen by dividing the vesicles carefully with the point of a fine scissors. The examinations of recent histologists, however, show, that the number is far beyond that mentioned by Roederer and others. At the period of puberty, the stroma of the ovary is crowded with ovisacs, which are still so minute, that in the cow, according to the computation of Dr. Barry, a cubic inch would contain 200 millions of them. Fluid from the ovary of a mare was examined by M. Lassaigne, and found to contain albumen, with chlorides of sodium and potassium.

Fig. 381.



Section of Ovary.

In the lower animals, the ovary consists of a loose tissue, containing many cells, in which the ova are formed, and from which they escape by the rupture of the cell-walls; in the higher animals, as in the human

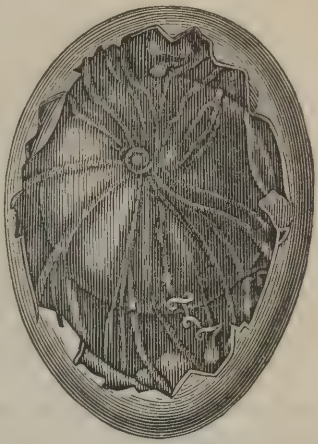
[1] Gazette Médicale de Paris, 25 Juin, 1842.

[2] Stannius, art. Eierstock, in Encyclop. Wörterb., u. s. w., x. 188, Berlin, 1836.

female, the tissue is more compact, and the ova, except when they are approaching maturity, can only be distinguished by the aid of a high magnifying power.

The microscopic analysis of the ovum has greatly engaged the attention of modern histologists, who have materially extended our knowledge in regard to it; although we have still much to learn. In the egg of the fowl, the parts more interesting in the present relation are the yolk membrane and its contents: for neither the albumen which forms the white, nor the shell membrane with its calcareous covering, exists in the ovum whilst in the ovary. They are added during its passage through the oviduct. Within the yolk, or vitellary membrane—*cuticula vitelli*—is the yolk—*vitellus*—consisting partly of albuminous granules, and partly of oil globules. Towards the centre, the yolk changes in some degree, being of a lighter colour, and the granules having more the appearance of cells, with minuter globules in their interior. The central portion is termed *discus vitellinus*. In the centre of the yolk of the unripe ovule is a larger cell, distinct in appearance from the rest, and having a nucleus in its walls. This is the *germinal vesicle*, or vesicle of Purkinje, so called from its first describer, and the nucleus is the *germinal spot*. In man and the mammalia, the ova contain the same parts; but, even when advanced, they are exceedingly minute, owing to the small quantity of vitellus that enters into their composition. The ripest ovum in the ovary of the human subject, and of the mammalia, does not generally measure more than from the fifteenth to the twentieth part of a line in diameter: it rarely happens, that they are as much as $\frac{1}{10}$th of a line. They vary, according to Bischoff, from $\frac{1}{240}$th to $\frac{1}{120}$th of an inch. Under the microscope, the Graafian vesicle is found to consist of an external and an internal membrane. The former—*tunic of the ovisac*, of Dr. Barry,[1] is extremely vascular; the latter, *ovisac* of the same observer—*membrana propria* of some—*vésicule ovulifère* of M. Pouchet[2]—is smooth and velvety, and derives its vessels from the former. The cavity, enclosed by these membranes, is far from being filled by the ovum; it contains, besides, a whitish or yellowish albuminous mass, which consists chiefly of granules, from the three hundredth to the two hundredth part of a line in diameter, connected together by a tenacious fluid, forming the *membrana granulosa*,—*couche celluleuse* of M. Coste.[3] Its density is unequal, and, towards some part of the periphery of the

Fig. 382.



New-laid Egg with its Molecule, &c.—(Sir E. Home.)

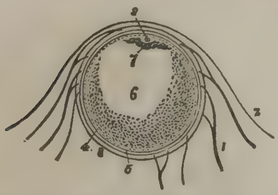
[1] Barry, Philos. Transact. for 1838.

[2] Théorie positive de l'Ovulation spontanée, p. 44, Paris, 1847.

[3] Histoire générale et particulière du Développement des Corps organisés, i. 163, Paris, 1847.

vesicle, these granules are accumulated in a disk-like form, making a slight prominence, in which there is a depression. The disk is termed by Von Baer *discus proligerus;* and it has been called *discus vitellinus.* The prominence has been named *cumulus, germinal cumulus, cumulus*

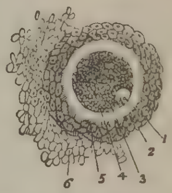
Fig. 383.



Section of the Graafian vesicle of a Mammal, after Von Baer.

1. Stroma of the ovary with blood vessels. 2. Peritoneum. 3 and 4. Layers of the external coat of the Graafian vesicle. 5. Membrana granulosa. 6. Fluid of the Graafian vesicle. 7. Granular zone or discus proligerus, containing the ovum (8).

Fig. 384.



Ovum of the Sow, after Barry.

1. Germinal spot. 2. Germinal vesicle. 3. Yolk. 4. Zona pellucida. 5. Discus proligerus. 6. Adherent granules or cells.

proligerus, nucleus cicatriculæ and *nucleus blastodermatis.* Dr. Barry likewise observed certain granular cords, resembling both in appearance and function the chalazæ of the egg, which he has called *retinacula*, but which Bischoff does not admit. A small cup-like cavity in the cumulus receives the ovum. The ovum is surrounded by a thick white ring, which has been called *zona pellucida*, and has been considered to be a membrane; but, according to Mr. T. W. Jones, is now pretty generally acknowledged to be "the optical expression of the circumferential doubling of a thick transparent membrane, which encloses the yolk." Within this, is a granular layer—the *vitellus* or *yolk*—the larger granules of which are superficial and compact; whilst, internally, it is a clear albuminous fluid almost devoid of granules. Imbedded in the vitellus, but nearer its circumference than its centre, is the *germinal vesicle*, or *vesicle of Purkinje*, first seen in the mammalia by M. Coste,[1] which appears like a clear ring of very small size, and measures in man and the mammalia not more than $\frac{1}{60}$th part of a line in diameter. Upon a particular part

Fig. 385.

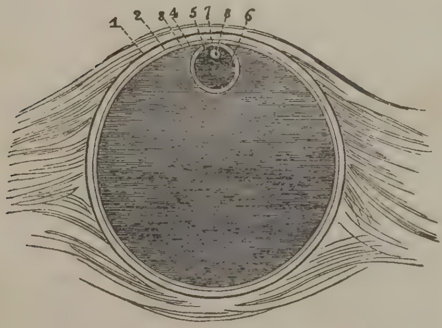


Diagram of a Graafian Vesicle, containing an Ovum.

1. Stroma or tissue of the ovary. 2 and 3. External and internal tunics of the Graafian vesicle. 4. Cavity of the vesicle. 5. Thick tunic of the ovum or yolk-sac. 6. The yolk. 7. The germinal vesicle. 8. The germinal spot.

[1] Bischoff, Traité du Développement de l'Homme et des Mammifères, traduit par Jourdan, p. 6, Paris, 1843.

of the germinal vesicle is observed the *macula germinativa* or *germinal spot*, which presents itself as a rounded granular formation attached to the inner wall of the germinal vesicle. All these parts are represented in Fig. 385. Wagner[1] thinks the germinal vesicle may be viewed as a cell—a primary cell—of which the germinal spot forms the nucleus, and that it would perhaps be well to style the germinal spot *germinal nucleus.*

Fig. 386.

Ovarium laid open, with Graafian vesicles in various stages of evolution. (Coste.)

At *p*, is shown the expanded fimbria of the Fallopian tube, near which is seen to project from the surface of the ovary a Graafian vesicle, *v*, the rupture of which has allowed an ovule, *æ*, surrounded by its discus proligerus, *c*, to escape;—in the centre of the upper part of the figure is shown an emptied Graafian vesicle, *v*, laid open by the incision, and showing the irregular cavity, *g*;—further up, towards the left, is seen another Graafian vesicle, with the ovum *c*, not yet discharged. Other Graafian vesicles, *v*, *v*, *v*, in earlier stages of developement, are seen in different parts of the figure.

It was elsewhere remarked,[2] that the formation of the ovule by the Graafian follicle must be regarded as a true secretion,—the yolk of which it is mainly composed as well as the membrana granulosa essentially resembling each other in histological and chemical character. When maturated, the ovum, pressed forward probably by fresh depositions of the yellow matter which goes to the formation of the granular membrane and the yolk, is discharged from the ovary, and laid hold of by the Fallopian tube, which acts as an excretory duct, and conveys it into the interior of the uterus.

[1] Human Physiology, translated by R. Willis, p. 43, Lond., 1841.
[2] Vol. ii. p. 281.

The observations of Carus[1] have shown, that the vesicles of De Graaf exist even in the fœtus; and according to Dr. Ritchie,[2] it would seem that during the period of childhood, there is a continual rupture of ovisacs, and discharge of ova at the surface of the ovarium.[3] The ovaria are studded with numerous minute copper-coloured spots; and their surface presents delicate vesicular elevations, occasioned by the most matured ovisacs: the escape of these takes place by minute punctiform openings in the peritoneal coat, and no cicatrix is left. The different conditions of progress towards maturation are well seen in the ovary or yolk bag of the common fowl.

Fig. 387.

Ovarium of the living Hen, naturul size. The Ova at different stages of evolution.—(Sir E. Home.)

The arteries and veins of the ovaries belong to the spermatic. The arteries pass between the two layers of the broad ligament to the ovarium, assuming there a beautiful convoluted arrangement, very similar to the convoluted arteries of the testis. These vessels traverse the ovary nearly in parallel lines, as in the marginal figure, forming numerous minute twigs, which have an irregular knotty appearance, from their tortuous condition; and appear to be chiefly distributed to the Graafian vesicles. The nerves of the ovaries, which are extremely delicate, are from the renal plexuses; and their lymphatics communicate with those of the kidneys.

Such is the anatomy of the chief organs concerned in the function of generation. Those of lactation will be described hereafter.

MENSTRUATION.

Before proceeding to the physiology of generation, there is a function, peculiar to the female, which requires consideration. This consists in a periodical discharge of blood from the vulva, occurring from three to six days in every month, during the whole time that the female is capable of conceiving,—or from the period of puberty to what has been termed the *critical age*. This discharge is called *catamenia*, *menses*, *flowers*, &c., and the process *menstruation*. It has been considered

[1] Gazette Médicale de Paris, Aug. 12, 1837. [2] Lond. Med. Gazette, 1844.
[3] Kirkes and Paget, Handbook of Physiology, Amer. edit., p. 461, Philad., 1849.

peculiar to the human species; but MM. Geoffroy St. Hilaire, and F. Cuvier, assert, that they have discovered indications of it in the females of certain animals. It has been denied, however, that this is anything more than the exudation of a bloody mucus. At the present day, however, menstruation is maintained by many to be identical with the *rut* of animals.

In some females, it is established suddenly, and without any premonitory phenomena; but in the greater number it is preceded and accompanied by some inconvenience. The female complains of signs of plethora or general excitement,—indicated by redness and heat of skin, heaviness in the head, oppression, quick pulse, and pains in the back or abdomen. The discharge commences drop by drop, but continuously: during the first twenty-four hours, the flow is not as great as afterwards, and is more of a serous character; but, on the following day, it becomes more abundant and sanguineous, and gradually subsides, leaving, in many females, a whitish, mucous discharge, technically termed *leucorrhœa*, and, in popular language, the *whites*.

The quantity of fluid lost, during each menstruation, varies greatly according to the individual and the climate. Its average is supposed to be from six to eight ounces in temperate climes. By some, it has been estimated as high as twenty. Dr. Meigs[1] states, that he has met with many healthy women, who informed him, that they never used a napkin; so that, he observes, it is not possible to conceive, that in such persons the loss amounts to more than three or four ounces. It is difficult, indeed, to imagine that it can amount to as much. On the other hand, he is confident, that many healthy females lose at least 20 ounces at each period.

The fluid proceeds from the interior of the uterus, and not from the vagina. At one time, it was believed, that in the intervals between the flow of the menses, the blood gradually accumulates in some parts of the uterus, and when these parts attain a certain degree of fulness, they give way, and it flows. This office was ascribed to the cells, which were conceived to exist in the substance of the uterus between the uterine arteries and veins,—and, by some, to the veins themselves, which, owing to their great size, were presumed to be reservoirs, and hence called *uterine sinuses*. The objection to these views is,—that we have no evidence of the existence of any such accumulation; and that when the interior of the uterus of one who has died during menstruation is examined, there are no signs of any such rupture as that described; the enlarged vessels exist only during pregnancy or during the expanded state of the uterus; the veins in the unimpregnated uterus are small, and totally inadequate for such a purpose.

The menstrual fluid is a true exhalation, effected from the inner surface of the uterus. This is evident from the change in the lining membrane of the organ during the period of its flow, which is rendered softer and more villous, and exhibits bloody spots, with numerous pores from which the fluid may be expressed. An injection, sent into the arteries of the uterus, also readily transudes through the lining mem-

[1] Edit. of Colombat de l'Isère on the Diseases, &c., of Females, p. 33, Philad., 1845.

brane. The appearance of the menstrual fluid in the cavity of the uterus, during the period of its flow; its suppression in various morbid conditions of the organ; and the direct evidence, furnished to Ruysch, Blundell,[1] Sir C. Clarke,[2] and others, in cases of prolapsus or inversio uteri, where the fluid has been seen distilling from the uterus, likewise show that it is a uterine exhalation.

Much discussion has occurred as to whether the catamenia are the result of simple hemorrhage; or are a true secretion from the uterine blood. From ordinary blood they may be distinguished by the smell, which is *sui generis*, and also by not being coagulable. "It [the menstrual fluid] is," says Mr. Hunter, "neither similar to blood taken from a vein of the same person, nor to that which is extravasated by accident in any other part of the body, but is a species of blood, changed, separated, or thrown off from the common mass by an action of the vessels of the uterus, similar to that of secretion, by which action the blood loses the principle of coagulation, and, I suppose, life." The principle of coagulation does not exist,—according to Lavagna, Toulmouche, J. Müller and others,[3] owing to the absence of fibrin. Retzius[4] asserts, that he has detected in it free phosphoric and lactic acids, by the presence of which, he conceives, the fibrin is kept in a state of solution, and prevented from coagulating. The fluid has the properties, according to Mr. Brande, of a very concentrated solution of the colouring matter of the blood in a dilute serum.[5] Dr. Burow[6] examined twelve ounces of menstrual blood, which had been retained in the uterus by an imperforate hymen. It was of a dirty reddish-brown colour, of the consistence of syrup, very adhesive, and entirely devoid of odour; abounded in albumen, and was very little susceptible of putrefaction. When examined with the microscope, almost all the blood-corpuscles were found to have lost their regular form, and to resemble the granules observed in pus which has been for a long time exposed to the air, or retained within the cavity of an abscess. These blood-corpuscles were suspended in a transparent fluid. On stirring the blood for a considerable time, no perceptible change was produced to the eye; but under the microscope numerous delicate, transparent lamellæ were seen floating in the serum, which Dr. Burow regarded as portions of fibrin, a substance sparingly present—as has been remarked—in menstrual blood. The red colour of the menstrual fluid was found by Remak[7] to be owing to the presence of blood-corpuscles, and the intensity of the colour to their number. M. Bouchardat[8] analyzed the menstrual fluid, obtained from a female who permitted a speculum to remain in the vagina for ten hours, in order that an ounce might be procured. Without this

[1] Principles and Practice of Obstetricy, Amer. edit., p. 49, Washington, 1834.

[2] On Diseases of Females attended with Discharges, Amer. edit., Philad., 1824.

[3] Handbuch der Physiologie, Baly's translation, p. 256, Lond., 1837, and p. 1481, Lond., 1842.

[4] Ars. Berättelse af Setterblad, 1835, Seite 19—cited in Zeitschrift für die Gesammte Medicin, Marz, 1837, s. 390.

[5] Philos. Transact., ciii. 113; and Blundell, op. cit., p. 46.

[6] Müller's Archiv., No. vii. 1840; and Brit. and For. Med. Rev., July, 1840, p. 287.

[7] Medicinische Zeitung, 25 Dec., 1839.

[8] Brière de Boismont, De la Menstruation, &c., Paris, 1842.

precaution, the fluid becomes mixed with vaginal mucus and urine, as the presence of ammoniaco-magnesian phosphate demonstrates. The following were the results of the analysis:—Water, 90·8; fixed matters, 6·92. The fixed matters were composed of—fibrin, albumen, and colouring matter, 75·27; extractive matter, 0·42; fatty matter, 2·21; salts, 5·31; mucus, 16·79. The female was a patient of M. Brière de Boismont, who considers, that the large proportion of water was due to the delicacy of her frame, and to her subsisting on vegetable diet (?).

A specimen of menstrual blood was examined by M. Simon,[1] and found to be composed of water, 785·000; solid constituents, 215·000; fat, 2·580; albumen, 76·540; hemato-globulin, 120·400; extractive matters and salts, 8·600. It contained no fibrin. Its most striking peculiarities were;—the total absence of fibrin, and the increase of solid constituents caused by the excess of blood-corpuscles. The hemato-globulin was found to be very rich in hematin, combined, undoubtedly, with a considerable amount of hemaphæin. The colouring matter amounted to 8·3% of the hemato-globulin. M. Simon has, however, little doubt that fibrin exists in the menstrual secretion; but its detection is usually rendered impracticable, owing to the presence of a large amount of mucus, which seems to deprive the blood of its power of coagulating.

In an analysis made by M. Denis, and cited by M. Coste,[2] the menstrual fluid was found to consist of water, 82·50; fibrin, 0·05; hematosin, 6·34; mucus, 4·53; albumen, 4·83; oxide of iron, 0·05; red phosphuretted fat and traces of white phosphuretted fat, 0·39; osmazome and cruorin, of each, 0·11; subcarbonate, chlorohydrate of soda, and chlorohydrate of potassa, of each, 0·95; carbonate of lime and sulphate of lime, 0·25; traces of phosphate of magnesia:—the whole consisting of 82·50 watery parts; 10·70 parts in suspension and in globules; and 6·58 parts in solution.

Rindskopf analyzed the menstrual discharge of a healthy vigorous girl. It was extremely acid, and contained on the first analysis, water, 820·830; solid residue, 179·170; salts, 10·150;—in the second, water, 822·892; albumen and hemato-globulin, 156·457; extractive matter and salts, 20·651. Another specimen of menstrual fluid, examined by M. Donné, presented the following appearances under the microscope. 1. Abundance of ordinary corpuscles of the blood. 2. Vaginal mucus, formed of epidermic scales from the mucous membrane. 3. Mucous globules, furnished by the neck of the uterus (?). In more than fifty specimens of the ordinary menstrual fluid, examined by Mr. Whitehead,[3] the following were the results:—its acid nature was in every instance unequivocal; its colour was similar to that of healthy venous blood, never so florid as that from the arteries; and it was less viscid than either; it did not coagulate, but occasionally,—when very profuse owing to over-exertion, mental anxiety, or confinement to a

[1] Animal Chemistry, by Day, Sydenham edit., p. 337, Lond., 1845.
[2] Histoire Générale et Particulière du Développement des Corps Organisés, p. 224, Paris, 1847.
[3] On the Causes and Treatment of Abortion and Sterility, Amer. edit., p. 40, Philad., 1848.

heated atmosphere,—clots were observed, which always had an alkaline reaction: under the microscope blood-corpuscles in linear or irregular groups were always observable, floating in a pale, pinkish serum; and occasionally a few lymph globules were perceptible, with a number of small granular bodies like oil globules: there was always, also, in it a great quantity of epithelial scales of different shapes and sizes.

So far, therefore, as examinations go, they show, that there is much resemblance between the catamenial discharge and blood. M. Donné,[1] indeed, affirms, that they appear to him to differ in no respect; and, that if the former has occasionally an acid reaction, in place of being alkaline like ordinary blood, this is simply owing to its being mixed with a considerable quantity of vaginal mucus, which is always extremely acid; whilst uterine mucus, he affirms, is always alkaline.[2] The question, whether it be a secretion or a periodical hemorrhage is one of slight moment. They, who are of the former opinion, believe, that the fluid differs somewhat from blood as contained in the vessels; and if such difference really exists, they must regard it as a secretion. They, on the other hand, who maintain the latter opinion, believe the fluid to be pure blood, which subsequently becomes mixed with the utero-vaginal secretions; and that the peculiar odour is occasioned by such admixture. The author has been assured, however, by one observer, that in a case of vicarious catamenial discharge, which took place from the hairy scalp, the peculiar odour was distinctly evinced. This is a point which merits farther observation. That the flow takes place from the arteries and not from the veins, is favoured by the fact, that when injections are sent into the uterine arteries they transude through the lining membrane of the uterus; and the analogy of all the other exhalations is confirmatory of the position.

The efficient cause of menstruation has afforded ample scope for speculation and hypothesis. As its recurrence corresponds to a revolution of the moon around the earth, lunar influence has been invoked; but, before this solution can be admitted, it must be shown, that the effect of lunar attraction is different in the various relative positions of the moon and earth. There is no day in the month, in which numerous females do not commence their menstrual flux; and, whilst the discharge is beginning with some, it is at its acme or decline with others. The hypothesis of lunar influence must therefore be rejected. In the time of Van Helmont,[3] it was believed, that a ferment exists in the uterus, which gives occasion to a periodical intestine motion in the vessels, and a recurrence of the discharge; but independently of the want of evidence of the existence of such a ferment, the difficulty remains of accounting for its regular renovation every month. Local and general plethora have been assigned as causes; and many of the circumstances, that modify the flow, favour the opinion. The fact of what has been called *vicarious menstruation*, has been urged in support of this view. In these cases, instead of the menstrual flux taking place from the uterus, hemorrhage occurs from various other parts of the body, as the breast, lungs, ears, eyes, nose, &c., which would appear to indicate,

[1] Cours de Microscopie, p. 139. Paris, 1844. [2] Ibid., p. 155.
[3] Opera, edit. 4, p. 440, Lugd. Bat., 1667.

that there is a necessity for the monthly evacuation or *purgation*, Reinigung, as the French and Germans term it; and that if this be obstructed, a vicarious hemorrhage may be established; yet the loss of several times the quantity of blood from the arm, previous to, or in the very act of, menstruation does not always prevent, or interrupt the flow of the catamenia; and in those maladies, which are caused by their obstruction, greater relief is afforded by the flow of a few drops from the uterus itself, than of ten times the quantity from any other part.

Some of the believers in local plethora of the uterus have maintained, that the arteries of the pelvis are more relaxed in the female than in the male, and the veins more unyielding; and hence, that the first of these vessels convey more blood than the second return. It has been, also, affirmed, that whilst the arteries of the head predominate in man by reason of his being more disposed for intellectual meditation, the pelvic and uterine arteries predominate in the female, owing to her destination being more especially for reproduction. Setting aside all these gratuitous assumptions, it is obvious, that a state, if not of plethora, at least of irritation, must occur in the uterus every month, which gives occasion to the menstrual secretion; but as M. Adelon[1] has properly remarked, it is not possible to say why this irritation is renewed monthly, any more than to explain, why the predominance of one organ succeeds that of another in the progress of age. The function is as natural, as instinctive to the female, as the developement of the whole sexual system at the period of puberty. That it is connected most materially with the capability of reproduction is shown by the fact, that it does not make its appearance until puberty,—the period at which the young female is capable of conceiving,—and disappears at the critical time of life, when conception is impracticable. It is arrested, too, as a general rule, during pregnancy and lactation; and in amenorrhœa or obstruction of the menses, fecundation is not readily effected. In that variety, indeed, of menstruation, which is accomplished with much pain at every period, and is accompanied by the secretion of a membranous substance having the shape of the uterine cavity, conception may be esteemed impracticable. Professor Hamilton, of the University of Edinburgh, was in the habit of adducing this in his lectures, as one of two circumstances—the other being the want of a uterus—that are invincible obstacles to fecundation. Yet, in the case of dysmenorrhœa of the kind mentioned, if the female can be made to pass one monthly period without suffering, or without the morbid secretion from the uterine cavity, she may become pregnant, and the whole of the evil be removed: for, the effect of pregnancy being to arrest the catamenia, the morbid habit is usually got rid of during gestation and lactation; and may not subsequently recur.

Gall[2] strangely supposed, that some general but extraneous cause of menstruation exists, other than the influence of the moon; and affirms, that in all countries females generally menstruate about the same time;—that there are, consequently, periods of the month in which none are in that condition; and he affirms, that all females may, in this

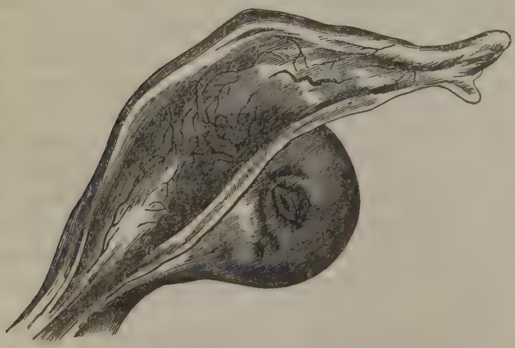
[1] Physiologie de l'Homme, 2d edit., iv. 48, Paris, 1829.
[2] Sur les Fonctions du Cerveau, iv. 355.

respect, be divided into two classes:—the one comprising those who menstruate in the first eight days of the month, and the other, those who are "unwell"—as it is termed by them in some countries—in the last fortnight. He does not, however, attempt to divine what this cause is. We are satisfied, that his positions are erroneous. Observation has led to the knowledge, already stated, that there is no period of the moon at which the catamenial discharge is not taking place in some; and we have not the slightest reason for supposing, that, on the average, more females are menstruating at one part of the month than at another. It would seem, however, that there are circumstances in the economy, which, as in the case of fevers, give occasion to something like periodicity at intervals of seven days;—for example, Mr. Roberton,[1] of Manchester, England, asserts, that of 100 women, the catamenia returned every fourth week in 68; every third week in 28; every second week in 1; and at irregular intervals in 10; these varieties usually existing as family and constitutional peculiarities.

It is scarcely necessary to notice the visionary speculations of those who have regarded menstruation as a mechanical consequence of the erect attitude; or the opinion of Roussel,[2] that it originally did not exist, but was produced artificially by too succulent and nutritious a regimen, and afterwards propagated from generation to generation; or, finally, that of Aubert, who maintained, that if the first amorous inclinations were satisfied, the resulting pregnancy would totally prevent the establishment of menstruation. The function, it need scarcely be repeated, is instinctive; and forms an essential part of the female constitution.

M. Gendrin,[3] and others, have revived a view entertained by Mr. Cruikshank, Dr. Power,[4] and others, that menstruation is dependent upon changes occurring periodically in the ovary. Many cases have been related by Cruikshank, Robert Lee, Gendrin, Négrier, Bischoff, Pouchet, and others,[5] in which, on the dissection of females, who had died during menstruation, evidences have been afforded of the rupture of an ovarian vesicle, and of a small irregular rupture or cicatrix in the coats of the ovarium, as represented in the mar-

Fig. 388.



Ovary of a Female dying during Menstruation.

[1] Edinb. Med. and Surg. Journal, xxxviii. 237.
[2] Système Physique, &c., de la Femme, p. 13, Paris, 1809.
[3] Traité Philosophique de Médecine pratique, Paris, 1838–9.
[4] An Essay on the Periodical Discharge, &c., London, 1832.
[5] See, on this subject, Coste, Histoire Générale et Particulière du Développement des Corps Organisés, p. 195, Paris, 1847.

ginal figure, which communicated with the remains of a Graafian vesicle; whence it has been inferred, that during the whole of that period of life when the capability for conception continues, there is a constantly successive developement of vesicles and their contained ovules in the ovary, and that, at each epoch of menstruation, a vesicle having reached the surface of the ovary becomes the seat of a peculiar organic action, in which all the organs of generation participate; and that the result of this action is the rupture of the vesicle, and the loss of the infecund ovum, either by expulsion from the uterus or by destruction in the ovary. Subsequently, M. Raciborski[1] maintained as the result of his researches,—*First.* That there exists the most intimate connexion between the Graafian vesicles and menstruation. When the vesicles arrive at their full developement, menstruation commences, and when they are destroyed, it ceases. *Secondly.* At each menstrual period, a follicle projects like a nipple on the surface of the ovary, where it afterwards bursts, without requiring for that purpose any venereal excitement. *Thirdly.* The rupture of the follicles generally appears to take place at the period when the menstrual discharge is stopping; and *Fourthly.* The ovaries do not act alternately, as has been affirmed;—in this respect not seeming to be under any fixed law. In a more recent work,[2] he asserts the doctrine, that the catamenia are but a secondary phenomenon in menstruation properly so called; that the capital phenomenon is the maturation and periodical discharge (*ponte*) of ova; and hence, a woman may give birth to several children without ever having seen the catamenia. Of late years, much attention has been given to this subject, and by none more than by Dr. Ritchie,[3] of Glasgow. As before remarked, this gentleman affirms, that even during the period of childhood, there is a continual rupture of ovisacs, and discharge of ova at the surface of the ovary. About the period of puberty—he states—a marked change usually takes place in the mode in which the ovisacs discharge their contents; but this change does not necessarily occur simultaneously with the first appearance of the catamenia. The ovaries now receive a much larger supply of blood, and the ovisacs exhibit a great increase of bulk and vascularity, so that when they appear at the surface of the ovary, they resemble pisiform turgid elevations; and the discharge of their contents leaves a much larger cicatrix, and is accompanied by an effusion of blood into their cavities. It would appear, however, from Dr. Ritchie's observations, that although this discharge takes place most frequently at the menstrual period, the two occurrences are not necessarily coexistent; for menstruation may occur without any such rupture; and, on the other hand, the maturation and discharge of mature ova may occur in the intervals of menstruation, and even at periods of life when that function is not taking place—as before the age of puberty;[4] and Dr.

[1] Bullet. de l'Académ. Royal de Méd., Jan., 1843.

[2] De la Puberté et de l'Age Critique chez la Femme, et sur la Ponte des Mammifères, &c., Paris, 1844.

[3] London Medical Gazette, 1843; Lond. and Edinb. Monthly Journal of Med., Aug., 1845, or Amer. Journal of Med. Sciences, Oct., 1845, p. 431, and Jan., 1846, p. 185.

[4] The same view is maintained by Mr. Kesteven, London Medical Gazette, for Nov.,

Ashwell[1] has related three cases in which he examined the ovaria of women, who had died during the menstrual flow, and in none was there the physical evidence of a maturated or rent Graafian vesicle; and he properly remarks, that it is by observation on the human female alone that the point can be settled. Moreover, it is important to bear in mind, in connexion with this subject, that although the discharge of ova may, and does, occur independently of sexual intercourse and excitement, M. Coste—as elsewhere remarked—has shown, that sexual intercourse may hasten their discharge, and he draws attention to what is observed in animals in the wild and in the domesticated state. In the former condition "incessantly occupied with their own preservation, often exposed to the inclemency of the weather, and unable to procure sufficient nutriment, the functions of the ovaries are executed at rare intervals. But when they are sheltered in our dwellings, and are subjected to all the favourable conditions that domestication procures them, the maturation of ova may become so frequent that, with certain species, the *ponte* may be almost daily."[2] He has satisfactorily shown, moreover, that the recurrence of the period of heat is amazingly hastened by the presence and efforts of the male; and judiciously concludes:—"If, in birds, shelter, warmth, and nourishment can multiply the periods for the maturation and discharge of ova, and if in the mammalia the same causes, combined with the excitement of the male, are powerful enough to produce the same result, it would not be rational to suppose that the human species, which can be placed at its pleasure under all these conditions, and gathers around it all the benefits of civilization, should be inaccessible to these influences; and, by an inexplicable exception, should remain invariably restricted within the insurmountable limits of the menstrual periods. Such a supposition would be the more unreasonable, seeing—as I have already remarked—that woman has, and the females of the mammalia have not, the privilege of a permanent aptitude for sexual intercourse; and, consequently, the activity which the male influence can impress on the functions of her ovaries, ought to be more intense than in the mammalia, in which such influence is much less direct, as it is reduced to simple efforts, that are resisted by the female."

The essential condition of menstruation would seem to be increased turgescence of the vessels of the uterus, and the appearance, on its inner surface, of a fresh wall of deciduous villous vessels, the morphology of which is analogous to that of the decidua of pregnancy. M. Coste[3] affirms, that he is possessed of twenty wombs of persons who were suicides, or died of some violent death, in which there was hypertrophy of the lining membrane of the uterus, the result of erethism; but in no case were there the floating villosities mentioned by Baer and E. Weber, or the pseudo-membranous exudation which may remain for at least two weeks, described by almost all physiologists.

1849; see, also, Whitehead, On the Causes and Treatment of Abortion and Sterility, Amer. edit., p. 49, Philad., 1848.

[1] A Practical Treatise on the Diseases Peculiar to Women, 3d edit., Lond., 1848.

[2] Op. cit., p. 224.

[3] Op. cit., p. 210.

It has been much urged of late, as it was formerly, that there is a striking analogy between menstruation, and the *rut* or period of heat in animals; and so far as regards the maturation of ova, and the periodical secretion from the genital organs in the two conditions there may be ground for the analogy; but in other respects it is forced, and unsatisfactorily supported. Heat in animals means "venereal heat"—*ardor venereus*—and at that time only does the female admit the male; whilst the human female receives him at all times. It has been attempted, indeed, to show, that the human female, during menstruation, has the same increase of venereal ardour, and that the capability for impregnation is at this time at its acme; but this is not in accordance with exact observation.

That the aptitude is greater immediately after menstruation has been maintained since the time of Hippocrates.[1] It has been an old remark, too, that some are only capable of conception during the flow of the catamenia.[2] Müller,[3] Burdach,[4] and others, have denied, however, the greater sexual feeling during the flow; and the author, after careful inquiry, has met with nothing to confirm it. *After* the menstrual period, it can be understood, that more feeling may exist, owing to sexual intercourse having been for a time interrupted; yet it would appear, that impregnation frequently occurs immediately *before* the last catamenial discharge. "The fact," says Dr. Carpenter,[5] "that conception often takes place *before* the last appearance of the catamenia (and not *after* it, as commonly imagined), is one well known to practical men." He is one of those who think "there is good reason to believe, that in women the sexual feeling becomes stronger at that epoch [the menstrual]; and it is quite certain," he says, that "there is a greater aptitude for conception immediately *before* and *after* menstruation, than there is at any intermediate period."

It would be strange, however, if the period of greatest aptitude for conception should be the one at which there is, and always has been, a repugnance to sexual union on the part of both sexes. Bischoff and Mr. Girdwood,[6] consider this repugnance as the result of habit, and the natural delicacy of the sex, rather than of actual disrelish; but this is by no means proved: on the contrary, facts would seem to establish the reverse. As confirmatory of the view, it has been affirmed by M. Raciborski[7]—who is, by the way, an ardent and enthusiastic observer—that the exceptions to the rule, that conception occurs immediately before, or immediately after, or during menstruation, are not more than six or seven per cent.; and that "of fifteen women, who specified accurately [?] the period of their latest menstruation, as well as the dates of the connubial act, five conceived from coitus taking place from two to four days previous to the period at which the catamenial dis-

[1] De Natura Puer., cap. iii.; Pliny, Hist. Nat., sect. vii. lib. 18; Galen, De Semine, lib. i.

[2] Aristotle, Hist. Animal, lib. vii. cap. ii., Ambrose Paré, De Homin. Gener. liber. See, on all this subject, Prof. Litzmann, art. Schwangerschaft, Wagner's Handwörterbuch der Physiologie, 13te Lieferung, s. 47, Braunschweig, 1846, and Coste, op. cit., p. 190.

[3] Physiology, by Baly, p. 1482.

[4] Die Physiologie als Erfahrungswissenschaft, i. 250, 2te Auflage, Leipz., 1835.

[5] Op. cit.

[6] London Lancet, Dec. 7 and 14, 1844.

[7] London Lancet, Jan. 28, 1843, and in op. cit.

charge was due; in seven, conception was dated from coitus occurring two or three days after menstruation; in two, it took place at the actual period of the catamenia; and in only one so long as ten days after." Even in the exceptional case—we are told—the catamenia made their appearance shortly after the coitus, which took place at about the middle of the interval between the two regular periods.

These statements may be taken for what they are worth. Even if the facts were accurately observed, of which doubt may be entertained, they are numerically insufficient to enable any positive conclusions to be drawn: certainly, we are not sanctioned in inferring, that excepting within a short period before and after menstruation, the female is not likely to conceive, when—as before remarked—it has been sufficiently proved, that she is throwing off from the ovary infecund ova at other periods than the menstrual, and when there are unquestioned examples of fecundation resulting from a single coitus at an advanced stage of the intermenstrual period. All that we are perhaps justified in admitting, from recent observations, is, that there is a connexion between menstruation and the condition of the ovaries, regarding which, indeed, there ought to have been no doubt, as in a celebrated case of removal of both ovaries by Mr. Pott, menstruation entirely disappeared, although, previous to the removal, puberty existed, and the function had been well executed; and in disorganization of both ovaries the same thing has been observed;[1]—that ova are at this time, as at others, maturated and discharged into the Fallopian tubes;—and that changes occur in the lining of the uterus accompanied by a peculiar discharge;—the ovarian and uterine changes being simultaneous, and *perhaps* the latter being consequent on the former; but we have not approached, in the slightest degree, to a knowledge of the purpose served by the periodical catamenial secretion. If the periodical discharge of ova be menstruation, why is it, that the catamenial flow does not always accompany the maturation and discharge of ova?

The bearings of these views on impregnation and the formation of corpora lutea will be given hereafter.

The age, at which menstruation commences, varies in individuals and climates. It has been esteemed a general law, that the warmer the climate, the earlier the discharge takes place, and the sooner it ceases; but there is reason for doubting the correctness of this prevalent belief. With us, the most common period of commencement is from thirteen to seventeen years. Mahomet is said to have consummated his marriage with one of his wives, "when she was full eight years old."[2] Of 450 cases, observed at the Manchester Lying-in Hospital, in England,[3] menstruation commenced in the eleventh year in 10; in the twelfth in 19; in the thirteenth in 53; in the fourteenth in 85; in the fifteenth in 97; in the sixteenth in 76; in the seventeenth in 57; in the eighteenth in 26; in the nineteenth in 23; and in the twentieth in 4. Menstruation commonly ceases in the temperate zone at from forty to fifty years. These estimates are, however, liable to many

[1] Ashwell, A Practical Treatise on the Diseases peculiar to Women: Amer. edit. by Dr Goddard, p. 49, Philad., 1845.

[2] Prideaux, Life of Mahomet, p. 30, London, 1718.

[3] Roberton, op. citat.

exceptions, dependent upon individual differences. In rare cases, the catamenia have appeared at a very early age, even in childhood; and again, the menses with powers of fecundity have continued, in particular instances, beyond the ages that have been specified: in some of these protracted cases the catamenia have been regular; in others, the discharge, after a long suppression, has returned. Of 77 individuals, they ceased in 1 at the age of 35; in 4 at 40; in 1 at 42; in 1 at 43; in 3 at 44; in 4 at 45; in 3 at 47; in 10 at 48; in 7 at 49; in 26 at 50; in 2 at 51; in 7 at 52; in 2 at 53; in 2 at 54; in 1 at 57; in 2 at 60; and in one at 70. Of 10,000 pregnant females, registered at the Manchester Hospital, 436 were upwards of 40 years of age; 397 from 40 to 45; 13 in their 47th year; 8 in their 48th; 6 in their 49th; 9 in their 50th; 1 in her 52d; 1 in her 53d; and 1 in her 54th. Mr. Roberton asserts, that as far as he could ascertain,—and especially in the three cases above 50 years of age,—the catamenia continued up to the period of conception.

The following table, founded on the results of 2352 cases, has been published by M. Brière de Boismont.[1] It will be seen, that by far the greatest number of women begin to menstruate during the 14th or 15th year.

Age.	Paris, 1200 cases by Meniers.	Paris, 85 cases by Marc D'Espine.	Lyons, 432 cases by Pétrequin.	Marseilles, 68 cases by Marc D'Espine.	Manchester, 450 cases by Roberton.	Göttingen, 137 cases by Osiander.
5	1	0	0	0	0	0
7	1	0	0	0	0	0
8	2	0	0	0	0	0
9	10	1	0	0	0	0
10	29	0	5	0	0	0
11	93	3	14	6	10	0
12	105	14	26	10	19	3
13	132	6	47	13	53	8
14	194	18	50	9	85	21
15	190	14	70	16	97	32
16	141	7	79	8	76	24
17	127	6	58	4	57	11
18	90	5	38	2	26	18
19	35	8	21	0	23	10
20	30	3	9	0	4	8
21	8	0	5	0	0	1
22	8	0	1	0	0	0
23	4	0	0	0	0	1
24	0	0	3	0	0	0

Dr. Guy[2] has furnished some valuable statistics in regard to the period at which the function commences and ceases amongst females in England. From observations on 1500 cases, it appeared, that the greatest number first menstruated at the age of 15; the 14th year came next in order; then the 16th: whilst the number at 13 and 17, at 12 and 18, and at 11 and 19, approximated very closely to each other. Before the 11th, and after the 19th year, the numbers were very small. In more than half the cases, menstruation made its first appearance at 14, 15, and 16 years of age. The earliest period was 8, and the latest 25.

[1] De la Menstruation, &c., Paris, 1842.

[2] Medical Times, Aug. 9, 1845.

In regard to the period at which it ceases, he deduced from the results of 400 cases, that independently of disease, this might be at any period from the 27th to the 57th year. In the majority of cases it occurred between 40 and 50 years,—the number from 45 to 50 being greater than that from 40 to 45 years.

Mr. Roberton[1] has attempted, and successfully, to show, that the age of puberty is about as early in the cold, as in the tropical regions of the earth; and, that were marriages to take place in England at as juvenile an age as they do in Hindusthan, instances of very early fecundity would be as common in England as they are in that country. He is of opinion, that early marriage and early intercourse between the sexes, where found prevailing generally, "are to be attributed, not to any peculiar precocity, but to a moral and political degradation, exhibited in ill laws and customs, the enslavement more or less of the women, ignorance of letters, and impure or debasing systems of religion." He has also shown, from statistical evidence, that menstruation does not occur more early in the negress than in the white female: Dr. Vaigas, of Caraccas, indeed, in a letter to Professor Meigs, of Philadelphia, affirms, that precocious menstruation is more common in the white than in the coloured.[2]

It would seem, too, that when accurate investigations have been made, there is no striking difference between the age of puberty in the Esquimaux and in the women of Great Britain and this country. It is neither later owing to the rigour of the climate, nor earlier owing to race. Of 16 Esquimaux women, in regard to whom data on this subject were furnished to Mr. Roberton,[3] none menstruated under the age of 14; but, on the other hand, half the 16 Esquimaux menstruated under 16 years of age; whilst in corresponding data in regard to English women furnished by these observers, there was but one.

In the statement sent to Parliament by Bartholomew Mosse, when endeavouring to procure a grant for the Dublin Lying-in Hospital, he mentions, that 84 of the women delivered under his care were between the ages of 41 and 54; 4 of these were in their 51st year, and 1 in her 54th. A relation of Haller had two sons after her 50th year; and children are said to have been born even after the mother had attained the age of 60. A woman at Whitehall, New York, was delivered of a child at the age of 64.[4] Holdefreund relates the case of a female, in whom menstruation continued till the age of 71; Bourgeois till the age of 80; and Hagendorn till 90; it is probable, however, that these were not cases of true menstruation, but perhaps of irregularly periodical discharges of blood from the uterus or vagina. On the other hand, it may be remarked, that in the year 1828, a lady was a visitor at Ballston Springs, who was a grandmother, although only 28 years of

[1] Edinburgh Med. and Surg. Journal, Oct., 1832, July, 1842, and July, 1845, p. 156; and London Med. Gazette, July 21, 1843.

[2] A Treatise on the Diseases and Special Hygiène of Females, by Colombat de l'Isère, translated by Dr. Meigs, p. 21, Philad., 1845.

[3] Edinburgh Medical and Surgical Journal; cited in London and Edinburgh Monthly Journal of Medical Science, March, 1845, p. 232.

[4] T. D. Mitchell, Western Lancet, Nov., 1846, p. 277.

age.[1] A case is, also, recorded of a female, who menstruated when one year old, and was pregnant at a little over 9. On the 20th of April, 1834, being 10 years and three days old, she was delivered of a child weighing 7¾ lbs.[2] Sir George Simpson[3] states, that during his visit to Woahoo, a woman, twelve years of age, was living, "who had already presented to an English husband three thriving pledges of connubial love;" and the case of a young girl has been recently recorded by Mr. John Smith,[4] who began to menstruate when ten years and six months old, and was delivered of a child at 11 years and seven months.[5]

As a general rule, the appearance of the menses denotes the capability of being impregnated, and their cessation the loss of such capability. Yet, as already remarked, females have become mothers without ever having menstruated. Foderé[6] attended a woman, who had menstruated but once—in her 17th year,—although 35 years of age, healthy, and the mother of five children. Morgagni instances a mother and daughter, both of whom were mothers before they menstruated. Sir E. Home[7] mentions the case of a young woman, who was married before she was seventeen, and, having never menstruated, became pregnant; four months after her delivery, she became pregnant again; and four months after the second delivery, she was a third time pregnant, but miscarried: after this she menstruated for the first time, and continued to do so for several periods, when she again became pregnant; and Mr. Harrison,[8] at a meeting of the Westminster Medical Society, remarked, that he knew an instance in which the mother of a large family had never menstruated;—yet Dr. Dewees[9] and Dr. Campbell[10] assert, that there is not a properly attested instance on record of a female conceiving previous to the establishment of the catamenia: the latter gentleman admits, however, that when an individual has once been impregnated, she may conceive again several times in succession, without any recurrence of the catamenia between these different conceptions, —because *he* has known a case of this kind, but not of the other!

During the existence of menstruation, the system of the female is more irritable than at other times; so that all exposure to sudden and irregular checks of transpiration should be avoided, as well as every kind of mental and corporeal agitation, otherwise the process may be impeded, or hysterical and other troublesome affections be excited. The sacred volume exhibits the feeling entertained towards the female, whilst performing this natural function. Not only was she regarded "unclean" in antiquity: she was looked upon, as Dr. Elliotson has remarked,[11] to be mysteriously deleterious. In the time of Pliny,[12] a

[1] Mitchell, op. cit., p. 276.
[2] Transylvania Med. Journ., vii. 417; cited by Mitchell, op. cit.
[3] An Overland Journey round the World, Amer. edit., Part 2, p. 61, Philad., 1847.
[4] Lond. Med. Gaz., Nov. 3, 1848.
[5] Other cases are given in Taylor, Medical Jurisprudence, 2d Amer. from 3d Lond. edit., p. 505, Philad., 1850.
[6] Médecine Légale, i. 393, Paris, 1813.
[7] Philosoph. Transact., cvii. 258; and Lect. on Comp. Anatomy, iii. 298.
[8] London Lancet, Jan. 19, 1839, p. 619.
[9] Compend. System of Midwifery, 8th edit., Philad., 1836.
[10] Introduction to the Study of Midwifery, Edin., 1833.
[11] Elliotson's Blumenbach, p. 465, Lond., 1828.
[12] Histor. Natural. xxvii.

menstruating female was considered to blight corn, destroy grafts and hives of bees, dry up fields of corn, cause iron and copper to rust and smell, drive dogs mad, &c., &c.; and it is firmly believed by many, that meat will not take salt if the process be conducted by one so circumstanced. La Motte[1] had implicit belief in this opinion, and carried the absurdity so far as to assert, that red-haired women are worse than others in this respect; and he gives an anecdote of a red-haired servant of his who spoiled some choice wine, as he was about to sit down to enjoy it. He asserts positively, that the instant she touched the bottles, the wine was converted into vinegar,—much to the annoyance of himself and guests.

The temperature of the vagina does not appear to be affected by menstruation or pregnancy.[2]

c. *Sexual Ambiguity.*

The sexual characteristics, in the human species, are widely separate; and two perfect sexes are never united in the same individual. Yet such an unnatural union has been supposed to exist; from the fabulous son of Ἑρμης and Αφροδιτη,—Mercury and Venus,—to his less dignified representative of modern times:—

> "Nec fœmina dici,
> Nec puer ut possent, neutrumque et utrumque videntur."—*Ovid.*[3]

We have already remarked, that in the lower animals, and in plants, such hermaphrodism is common; but, in the upper classes and especially in man, a formation that gives to an individual the attributes of both sexes has never been witnessed. Monstrous formations are occasionally met with; but if careful examination be made, it can usually be determined to what sex they belong. Cases, however, occur, in which it is difficult to decide, although we may readily pronounce, that the being is totally incapable of the function of reproduction. The generality of cases are produced by unusual developement of the clitoris in the female, or by a cleft scrotum in the male. Only two instances of the kind have fallen under the observation of the author, both of which were females, as they usually are. One of these has been described by the late Professor Béclard, of Paris, whose details we borrow.[4]

Marie-Madeleine Lefort, aged sixteen years, seemed to belong to the male sex, if attention were paid merely to the proportions of the trunk, limbs, shoulders, and pelvis; the conformation and dimensions of the pelvis; the size of the larynx; the tone of the voice, the developement of the hair; and the form of the urethra, which extended beyond the symphysis pubis. An attentive examination, however, of the genital organs showed, that she was of the female sex. The mons veneris was round, and covered with hair. Below the symphysis pubis was a clitoris, resembling a penis in shape, twenty-seven millimètres, or about an inch

[1] Traité des Accouchemens, p. 57.
[2] Fricke, Zeitschrift für die gesammte Medicin, Nov., 1838.
[3] "Both bodies in a single body mix,
A single body with a double sex."—*Addison.*
[4] Art. Hermaphrodite, in Dict. de Médecine, tom. xi.

long, in the state of flaccidity; and susceptible of slight elongation during erection; having an imperforate glans, hollowed beneath by a duct or channel, at the inferior part of which were five small holes situate regularly on the median line. Beneath and behind the clitoris, a vulva existed, with two narrow, short and thin labia furnished with hair, devoid of any thing like testicles, and extending to within ten lines of the anus. Between the labia was a superficial cleft, pressure upon which communicated a vague sensation of a void space in front of the anus. At the root of the clitoris was a round aperture, through which a catheter could not be passed into the bladder. It could be readily introduced, however, towards the anus, in a direction parallel to the perineum. When the catheter was passed a little backwards and upwards to the depth of eight or ten centimètres, it was arrested by a sensible obstacle; but no urine flowed through it. It seemed to be in the vagina. At the part where the vagina stopped, a substance could be distinguished through the parietes of the rectum, which seemed to be the body of the uterus. Nowhere could testicles be discovered. She had menstruated from the age of eight years; the blood issuing in a half coagulated state through the aperture at the root of the clitoris. She experienced, too, manifest inclination for the male, and a slight operation only would probably have been necessary to divide the apron, which closed the vulva from the clitoris to the posterior commissure of the labia. The urethra extended in this case for some distance beneath the clitoris, as in the penis; and from all the circumstances, M. Béclard concluded, that the person subjected to the examination of the *Société de Médecine* of Paris was a female: that she possessed several of the essential organs of the female,—the uterus and vagina,—whilst she had only the secondary characters of the male—as the proportions of the trunk and limbs, shoulders and pelvis; the conformation and dimensions of the pelvis; the size of the larynx; tone of the voice; developement of the hair; the urethra extending beyond the symphysis pubis, &c.

In the year 1818, a person was exhibited in London, who had a singular union of the apparent characteristics of both sexes. The countenance resembled that of the male, and there was a beard, but it was scanty. The shape, however, of the body and limbs was that of the female. The students of the Anatomical Theatre of Great Blenheim Street, London, of whom the author was one, offered her a certain sum, provided she would permit the sexual organs to be inspected by the veteran head of the school—Mr. Brookes: to this she consented. She was, accordingly, exposed before the class; and her most striking peculiarities exhibited. The clitoris was large, but not perforate. Mr. Brookes, desirous of trying the *experimentum crucis*, passed a catheter into the vagina, and attempted to introduce another into the urethra; but fearing discovery, and finding that the mystery of her condition was on the point of being unveiled, she started up and defeated the experiment. No doubt existed in the mind of Mr. Brookes, that there were two distinct canals,—one forming the vagina; the other the urethra,—and that she was, consequently, female.

One of the most complete cases of admixture of the sexes was de-

scribed by Rudolphi before the *Academy of Sciences* of Berlin, at the sitting of October 22, 1825.[1] It was met with in the body of a child, which died, it was said, seven days after birth; but the developement of parts led to the supposition, that it was three months old. The penis was divided inferiorly; the right side of the scrotum contained a testicle; the left was small and empty. There was a uterus, which communicated at its superior and left portion with a Fallopian tube, behind which was an ovary destitute of its ligament. On the right side, there was neither Fallopian tube, nor ovary, nor ligament, but a true testicle, from the epididymis of which arose a vas deferens. Below the uterus was a hard, flattened ovoid body, which, when divided, exhibited a cavity with thick parietes. The uterus terminated above in the parietes of this body, but without penetrating its cavity. At its inferior part was a true vagina, which ended in a cul-de-sac. The urethra opened into the bladder, which was perfect; and the anus, rectum, and other organs were formed naturally. Rudolphi considered the ovoid body, situate beneath the uterus, to be the prostate, and vesiculæ seminales, in a rudimental state.

A curious case of doubtful sex was seen by Dr. Pue, of Baltimore. It occurred in a negro, who had the appearance of a woman, and passed for such. On examination, at the request of her owner, Dr. Pue found no signs of female organs of generation. There was a penis of some developement—the size of a boy's 12 or 14 years old. The glans was well formed, but the urethra did not terminate at the extremity of the organ. It opened at the frænum. There was some appearance of scrotum, but no testes were perceptible. Menstruation took place regularly, but with great pain, the fluid passing through the urethra. During this period, the breasts—which were natural, and of the size of a girl's of 14—became tender and swollen, and she had sexual desire at this time only. The pubes was well covered with hair. Dr. Pue's impression was, that her inclinations were for the male. A similar case has been described by Dr. S. H. Harris, of Clarksville, Virginia.[2] A very interesting example has likewise been described by Professor Mayer[3] of Bonn. The mixed attributes of male and female were well marked. On the one hand, there was a testicle slightly atrophied, a penis and a prostate gland; on the other, a vagina and uterus, with its Fallopian tubes, and on the left side a body analogous to an ovary.

Cases like the above,—and we have such on the authority of Baillie, Verdier, Giraud, Ackermann, Handy, Sir E. Home, Pinel, Maret, Sue, Bouillaud, and others,—have led to the belief, that hermaphrodism is possible. Such is the opinion of Tiedemann, Meckel, and others. The varieties of these sexual vagaries are extremely numerous; and occasionally form the subject of medico-legal inquiry. A singular case, in which a question of civil rights was involved, has been detailed by Dr. William James

[1] Amer. Journ. of the Med. Sciences, p. 499, Feb., 1832.
[2] American Journal of the Medical Sciences for July, 1847, p. 121.
[3] Gazette Médicale de Paris, Sept. 24, 1836; cited in Philadelphia Med. Examiner, April, 10, 1841, p. 232.

Barry.[1] At a warmly contested election in Connecticut, in the spring of 1843, a person named Suydam was brought forward as a voter, who was challenged by the opposite party, on the ground that he was more female than male; and that he partook of the attributes of both sexes. On examining him, Dr. Barry found the mons veneris covered with hair in the usual way; there was an imperforate penis, subject to erection, about two inches and a half long. It had a well formed glans, with a depression in the usual seat of the orifice of the urethra, and a well defined prepuce and foramen. The scrotum was not more than half the usual size, and not pendulous. In it, on the right side, was a testicle, of the size of a common filbert, with a spermatic cord. At the root of the corpora cavernosa in the perineum, there was an aperture, through which the urine was discharged, large enough to permit the introduction of an ordinary sized catheter. From these appearances, Dr. Barry gave it as his opinion, that the person was a male citizen, and, consequently, entitled to vote. This decision was contested by Dr. Ticknor, who, however, after an examination, suggested by Dr. Barry, admitted, that Suydam was a male. He was accordingly allowed to vote; and the party ticket was carried by a majority of one. A few days after the election, Dr. Barry was informed, that Suydam had catamenia; and testimony was afforded, that he menstruated as regularly, but not as profusely, as most women. Drs. Barry and Ticknor now examined him together, with the following results. His height was five feet two inches; hair light coloured; complexion fair; chin beardless; temperament decidedly sanguineous; shoulders narrow; hips broad; and in short the figure was in all respects that of a female. The mammæ were well developed, with nipples and areolæ. On passing a female catheter into the opening through which the urine, as well as a monthly sanguineous flow, was discharged, the catheter, in place of entering the bladder, passed into a canal, similar to the vagina, three or four inches deep, in which the instrument had considerable play. Suydam stated, that he had erotic desires for the male sex, and his tastes and bodily powers resembled those of the female. It appeared, too, from proper testimony, that the aperture, through which the urine was discharged, was made by the accoucheur at the time of birth. Drs. Barry and Ticknor had, therefore, to renounce their previously expressed conviction that Suydam belonged to the male sex.

The case of an orang-outang, described by Dr. Harlan,[2] affords, perhaps the nearest approach to a complete union of the sexes in the same individual, which has been recorded. It had ovaries, Fallopian tubes, uterus, and vagina, and also testes, epididymis, vasa deferentia, and a highly erectile penis.

Instances of animals being brought forth, whose organs of generation are preternaturally formed, sometimes occur, and they, also, have been called *hermaphrodites;* but such examples have been rarely investigated. Monstrous productions, with a mixture of the male and female organs, seem to occur only in neat cattle, and have been called

[1] New York Journal of Medicine, &c., Jan., 1847.

[2] Medical and Physical Researches, p. 22, Philad., 1835.

free-martins. When a cow brings forth twin calves, one a male and the other apparently a female, the former always grows up to be a perfect bull; but the latter appears destitute of all sexual functions, and never propagates. This is the *free-martin.* It was the opinion of Mr. Hunter, that it never exhibits sexual propensities; but this has been controverted by Mr. Allnatt.[1] A clergyman of great respectability informed him, that he had bred a free-martin upon his estate, which had not only shown a natural desire for the male, but had admitted him—of course, ineffectually. Mr. Allnatt farther remarks, that he had seen, the day before, working in harness, a true, apparently female, adult free-martin, which occasionally manifested its male propensities in an intelligible manner. When the cows amongst which this free-martin is kept, exhibit their inclination for the male, the creature—unlike the spayed heifer or common ox—is peculiarly on the alert, and has been observed to leap them like the entire male. A gentleman of Mr. Allnatt's neighbourhood had a true free-martin, which had received the bull several times, but had never propagated. After death the animal was examined. Scarcely a vestige of uterus could be discovered. From Mr. Hunter's observations[2] it would seem, that in all the instances of free-martins, examined by him, no one had the complete organs of the male and female, but partly the one and partly the other; and, in all, the ovaria and testicles were too imperfect to perform their functions. In noticing this phenomenon, Sir Everard Home[3] remarks, that it may account for twins being most commonly of the same sex: "and when they are of different sexes," he adds, "it leads to inquire, whether the female, when grown up, has not less of the true female character than other women, and is incapable of having children." "It is curious," says Sir Everard, "and in some measure to the purpose, that, in some countries, nurses and midwives have a prejudice, that such twins seldom breed." Dr. Burns, too,[4] states it to be a popular opinion, and he does not know any instance to discountenance it, that if twins be of different sexes the female is sterile. These remarks are signally unfortunate, and ought not to have been hastily hazarded, seeing that a slight inquiry would have exhibited, that there is no analogy between the free-martin and the females in question; and, more especially, as the suggestion accords with a popular prejudice, highly injurious to the prospects, and painful to the feelings of all who are thus circumstanced. In the London Medical Repository,[5] Mr. Cribb, of Cambridge, England, has properly observed, that the external characters and anatomical conformation of the free-martin are totally unlike those of the human female. In external appearance, it differs considerably from the perfectly formed cow;—the head and neck, in particular, bearing a striking resemblance to those of the bull. Moreover, it is not true, that the free-martin cows never breed: Professor Simpson,[6] of Edinburgh, has referred to cases in which they were

[1] London Medical Gazette for July 2d, 1836.

[2] Animal Œconomy, edit. by Mr. Owen, Amer. edit., p. 70, Philad., 1840.

[3] Philosoph. Transactions for 1799; and Lectures on Comparative Anatomy, iii. 311, London, 1823.

[4] Principles of Midwifery, edit. of 1843.

[5] Sept. 1823, and Ibid., 1827.

[6] Edinb. Med. and Surg. Journ., Jan. 1844, p. 109.

fecund. Mr. Cribb has, however, brought forward most decisive evidence in favour of the fallacy of the popular prejudice, by the history of seven cases, which are of themselves sufficient to put the matter for ever at rest. Of these *seven*, which are all that he had ever known, of women, born under the circumstances in question, having been married,—*six* had children. The fullest and most satisfactory essay on this subject is, however, the one already referred to by Professor Simpson. By uniting together all the various cases, which he could collect, he found that he possessed the married history of 123 females born co-twins with males. The results, so far as they refer to this subject, are as follows: of 123, 112 had families, and 11 no issue, although married for several years. In other words, the marriages of females, born under such circumstances, were infecund in the proportion of 1 in 10. From other investigations he deduced, that this proportion does not exceed the degree of unproductiveness of marriages in the general community; and from the whole of his inquiries he arrives at the following important conclusions. *First.* That in the human subject, females, born co-twins with males, are, when married, as likely to have children as any other females belonging to the general community. *Secondly.* That when they are married and become mothers, they are, in respect to the number of their children, as productive as other females; and *Thirdly.* That the same law of fecundity of the female in opposite-sexed twins seems to hold good amongst all the uniparous domestic animals, with the exception of the cow.

It is certainly strange, that this exception should apply to the cow only; and that when she carries twins of the same sex—two males, or two females—they should be in all cases perfectly formed in their sexual organization, and both be capable of propagating. The whole series of circumstances, when considered in conjunction with each other—as is well remarked by Professor Simpson—seems to form, in relation to the origin of malformations, one of the strangest and most inexplicable facts to be met with in the study of abnormous developement.

2. PHYSIOLOGY OF GENERATION.

In man and the superior animals, in which each sex is possessed by a distinct individual, it is necessary that there should be a union of the sexes, and that the fecundating fluid of the male should be conveyed within the appropriate organs of the female, in order that, from the concourse of the matters furnished by both sexes, a new individual may result. To this union they are incited by an imperious instinct, established within them for the preservation of the species, as hunger and thirst are placed within them for the preservation of the individual. This has been termed the *desire* or *instinct of reproduction;* and for wise purposes its gratification is attended with the most pleasurable feelings, that man or animals can experience. Prior to the period of puberty, or whilst the individual is incapable of procreation, this desire does not exist; but it suddenly makes its appearance at puberty; persists vehemently during youth and the adult age, and disappears in advanced life, when procreation becomes again impracticable. It is strikingly exhibited in those animals, in which generation can only be effected at

particular periods of the year, or whilst they are in *heat;*—as in the deer, during the *rutting* season.

The views that have been entertained regarding the seat of this instinct—whether in the encephalon or genital organs—were considered under the head of the mental and moral manifestations. It was there stated, that MM. Cabanis and Broussais consider that internal impressions proceed from the genital organs, and form part of the psychology of the individual; and that Gall assigns an encephalic organ—the cerebellum—for their production, and ranks the instinct of reproduction amongst the primary faculties of the mind;—with what degree of truth, we have investigated elsewhere (vol. i. p. 353). In farther proof of the view that refers it to the encephalon, it may be remarked, that the instinct has been observed in those, who, owing to original malformation, have wanted the principal part of the genital organs, whilst it has continued in the case of eunuchs not castrated till after the age of puberty. In opposition to this view, it has been urged, that simple titillation of the organs excites the desire. This, however, may be entirely dependent upon association, in which the brain is largely concerned. In many cases, the desire is produced through the agency of vision; when the brain must necessarily be first excited, and, through its influence, the generative apparatus. The cause of the desire has, by some, been ascribed to the presence of sperm, in the requisite quantity, in the vesiculæ seminales; but in answer to this, it is urged, that eunuchs under the circumstances above mentioned, and females, in whom there is no spermatic secretion, have the desire. The fact is, we have no more precise knowledge of the nature of this instinct, than we have of any of the internal sensations or moral faculties. We know, however, that it exhibits itself in various degrees of intensity, and occasionally assumes an opposite character—constituting *anaphrodisia.*

a. *Copulation.*

In the union of the sexes, the part performed by the *male* is the introduction of the penis,—the organ for the projection of the sperm towards the uterus,—and the excretion of that fluid during its introduction. In the flaccid state of the organ penetration is impracticable; it is first of all necessary, that under the excitement of venereal desire the organ should attain a necessary degree of rigidity, which is termed *erection.* In this state it becomes enlarged, and raised towards the abdomen; its arteries beat forcibly; the veins are tumid; the skin is more coloured, and the heat augmented. It becomes also of a triangular shape; and these changes are indicated by an indescribable feeling of pleasure. Erection is not dependent upon volition. At times, it manifests itself against the will; at others refuses to obey it; yet it requires, apparently, the constant excitement of the encephalic organ concerned in its production,—the slightest distraction of the mind putting an end to it. The modest and retiring spouse is, at times, unable to consummate the marriage for nights, perhaps weeks; yet, he is only temporarily impotent; for the inclination and consequent erection supervene sooner or later. Pills of crumb of bread, and a recommendation to the indi-

vidual not to approach his wife for a fortnight, whatever may be his desire, have, in almost all cases, removed the impotence.

The state of erection is not long maintained, except under unusual excitement;—the organ soon returning to its ordinary condition of flaccidity. Its cause is a congestion of blood in the erectile tissue of the corpora cavernosa, urethra, and glans. Swammerdam and De Graaf cut off the penis of a dog during erection, and found the tissue gorged with blood, and that the organ returned to its flaccid condition as the blood flowed from it. The same fact, according to M. Adelon,[1] has been observed in the human subject, when erection has continued till after death. The author's late friend, Mr. Callaway,[2] of Guy's Hospital, London, has described the case of an individual, who, in a state of inebriation, had communication three times with his wife the same night, without the consequent collapse succeeding, although emission ensued each time. This state persisted for sixteen days, notwithstanding the use of appropriate means: at this time, an opening was made with a lancet into the left crus of the penis, below the scrotum; when a large quantity of dark, grumous blood, with numerous small coagula, escaped. By pressing the penis, the corpora cavernosa were immediately emptied, and each side became flaccid,—the communication by the pecten or septum penis permitting the discharge of the contents of both corpora by the incision. After recovery, the person remained quite impotent, the organ being incapable of erection,—probably owing, as Mr. Callaway suggests, to the deposition of coagulable lymph in the cells of the corpora cavernosa preventing the admission of blood, and the consequent distension of the organ. Artificial erection can, likewise, be induced in the dead body by injections, so that but little doubt need exist, that the enlargement and rigidity of the penis during erection are caused by the larger quantity of blood sent into it. The difficulty has been to account for this increased flow. The older writers ascribed it to the compression of the internal pudic vein against the symphysis pubis, owing to the organ being raised towards the abdomen by the ischio-cavernosi muscles; and as the cavernous vein empties its blood into the internal pudic, stagnation of blood in the corpora cavernosa ought necessarily to result from such compression, and consequent distension of the organ; whilst the cavernous arteries, being firmer, could not yield to the compression, and would, therefore, continue to convey blood to the penis. It is obvious, however, that here,—as in every case, where the erectile tissue is concerned,—the congestion must be of an active kind: the beating of the arteries and the coloration of the organ indicate this; and, besides, compression of the pudic vein cannot precede erection; it must, if it occurs at all, be regarded rather as a consequence of erection than as its cause. The case of the nipple of the female affords us an instance of erectility, where no compression can be invoked, and where the distension must be caused by augmented flow of blood by the arteries. If the nipple be handled, particularly whilst she is under voluptuous excitement, it enlarges, and becomes

[1] Physiologie de l'Homme, edit. citat., iv. 57.
[2] London Medical Repository, for April, 1824.

rigid, or is in a true state of erection. The correct opinion seems to be that irritation of this erectile tissue is the first link in the chain of phenomena constituting erection. The feeling of pleasure is certainly experienced there, prior to, and during erection; and this irritation, like every other, solicits an increased flow of blood into the erectile tissue, which, by organization, is capable of considerable distension. The erectile tissues of the corpora cavernosa, corpus spongiosum urethræ, and glans, are concerned in the process; but in what precise manner, physiologists are not entirely agreed. Some have supposed, that the blood is effused into the cells, and is consequently out of the vessels. Another view, supported by certain eminent anatomists and physiologists, is, that the blood simply accumulates in the venous plexuses of the corpora cavernosa. Such seems to have been the opinion of Tiedemann, Stieglitz, and J. Müller,[1] and of Cuvier, Chassier, and Béclard, from their injections; and the rapidity, with which erection disappears, favours the notion. The discovery of the helicine arteries of the penis by Professor Müller, described at page 377, has led to the inference that the peculiar arrangement may be concerned in the function in question, but in what manner the circulation in the male organ, or its erection, is modified by them has not been determined: Valentin, indeed,—as we have seen,—denies their existence.

It has been asked again, whether this accumulation of blood be, as we have remarked, an increased afflux by the arteries, or a diminished action of the veins; or these two states combined. The last opinion is probably the most correct. The arteries first respond to the appeal; the organ is, at the same time, raised by the appropriate muscles; its tissue becomes distended; the plexus of veins turgid, and the return of blood impeded. In this way, the organ acquires the rigidity necessary for penetrating the parts of the female. The friction, which then occurs, keeps up the voluptuous excitement, and the state of erection. This excitement is extended to the whole generative system; the secretion of the testicles is augmented; the sperm arrives in greater quantity in the vesiculæ seminales; the testicles are drawn up towards the abdominal ring by the contraction of the dartos and cremaster, so that the vas deferens is rendered shorter, and, in the opinion of some, the sperm filling the excretory ducts of the testicle is in this manner forced mechanically forwards towards the vesicles. When these have attained a certain degree of distension, they contract suddenly and powerfully, and the sperm is projected through the ejaculatory ducts into the urethra. At this period, the pleasurable sensation is at its height. When the sperm reaches the urethra, the canal is in the highest degree of excitement; and the ischio-cavernosi and bulbo-cavernosi muscles, with the transversi perinei, and levatores ani, are thrown into violent contraction; the first two holding the penis straight, and assisting the others in projecting the sperm along the urethra. By the agency of these muscles and of the proper muscular structure in the urethra, the fluid is expelled, not continuously, but in jets, as it seems to be sent into the urethra by the alternate contractions of the

[1] Art. Erection, in Encyclop. Wörterb. der Medicin. Wissenschaft., xii. 460, Berlin, 1834.

vesiculæ seminales. These muscular contractions are of a reflex character, being independent of the will, and incapable of being controlled by any exertion of it. They are induced, as in deglutition, by a special excitant,—the sperm in one case; the food in the other.

The quantity of sperm discharged varies materially according to the circumstances previously mentioned; its average has been estimated at about two drachms. Along with the true sperm, the fluids of the prostate and glands of Cowper are discharged; so as to constitute the semen as we meet with it. When the emission is accomplished, the penis gradually returns to its ordinary state of flaccidity; and it is usually impracticable, by any effort, to repeat the act without the intervention of a certain interval of repose, to enable the due quantity of sperm to collect in the spermatic vessels and vesicles. In some persons, however, the excitability is so great, and the secretion so ready, that little or no interval is required between the first and second acts. A singular case of satyriasis, well observed by Mr. Norris, of London, is recorded by him in the Latin language.[1] For two months the man had intercourse with his wife, according to his and her testimony, fifteen times each night, and occasionally twenty times, and always with emission!

This comprises the whole of the agency of the male in the function of generation.

In man, the emission of sperm is soon effected; but in certain animals it is a long process. In the dog, which has no vesiculæ seminales, the penis swells so much, during copulation, that it cannot be withdrawn until the emission of sperm removes the erection.

In the *female*, during copulation, the clitoris is in the same state of erection as the penis; so is the spongy tissue lining more especially the entrance of the vagina; and it is in these parts, particularly in the clitoris, that pleasure is experienced during sexual desire, and copulation. This feeling persists the whole time of coition, and ultimately attains its acme, as in the case of the male, but without any spermatic ejaculation. It is not owing to the contact of the male sperm,—for it frequently occurs before or after emission by the male, but is dependent upon some inappreciable modification in the female organs,—in the ovaries or Fallopian tubes, it is supposed by some physiologists. In most—if not in all—cases, an increased discharge suddenly takes place, during the orgasm, from the mucous follicles of the vagina and vulva, but chiefly from the glands of Duverney, the admixture of which with the male sperm is supposed to have some connexion with impregnation, and to be, perhaps, the vehicle for the fecundating principle of the sperm. After the kind of convulsive excitement into which the female is thrown, a sensation of languor and debility is experienced, as in the male,—but not to the same extent;—and, in consequence of no spermatic emission taking place in her, she is capable of a renewal of intercourse more speedily, and can better support its frequent repetition.

[1] Transactions of the Medical Society of London, vol. i. part i. p. 176, Lond., 1810.

b. *Fecundation.*

An admixture having, in this manner, been effected between the materials furnished by the male and female,—after a fecundating copulation *conception* or *fecundation* results, and the rudiments of the new being are instantaneously constituted. The well-known fact, that, after the removal of the testicles, the individual is incapable of procreation although the rest of the genital organs may remain entire, is of itself sufficient to show, that the fecundating fluid is the secretion of those organs, and that this fluid is indispensable. Physiologists have not, however, been satisfied with a knowledge of this fact. Spallanzani[1] examined frogs with great attention, whilst in the act of copulation, both in and out of water; and he observed, that, at the moment when the female deposits her eggs, the male darts a transparent liquid through a tumid point which issues from its anus. This liquid moistens the eggs, and fecundates them. To be certain that it is the fecundating agent, he dressed the male in waxed taffeta breeches; when he found, that fecundation was prevented, and sperm enough was contained in the breeches to be collected. This he took up by means of a camel's-hair pencil, and all the eggs which he touched with it were fecundated. Three grains of the sperm were sufficient to render a pound of water fecundating; and a drop of a solution, which could not contain more than the 2,994,687,500th part of a grain, was enough for the purpose. To diminish the objection, that the frog is too remote in organization from man to admit of any analogical deduction, Spallanzani took a spaniel bitch, which had engendered several times; shut her up some time before the period of *heat*, and waited until she exhibited evidences of being in that condition, which did not happen until after a fortnight's seclusion. He then injected into the vagina and uterus, by means of a common syringe warmed to 100° of Fahrenheit, nineteen grains of sperm obtained from a dog. Two days afterwards, she ceased to be in heat, and, at the ordinary period, brought forth three young ones, which not only resembled her but the dog from which the sperm had been obtained. This experiment has been repeated by Rossi, of Pisa, and Buffolini, of Cesena, with similar results.[2] The success of an analogous experiment on the human species rests on the authority of John Hunter. He recommended an individual, affected with hypospadias, to inject his sperm through a warm syringe. His wife became pregnant.[3]

In some experiments on generation, MM. Prévost and Dumas fecundated artificially the ova of the frog. Having expressed the fluid from several testicles, and diluted it with water, they placed ova in it. These were observed to become tumid and developed; whilst other ova, placed in common water, merely swelled up, and in a few days became putrid. They observed, moreover, that the mucus, with which the ova are covered in the *oviduct*,—the part corresponding to the Fallopian tube in the mammalia,—assists in the absorption of the sperm, and in

[1] Sur la Génération, par Senebier, Genév., 1783.
[2] Adelon, Physiologie de l'Homme, iv. 66, Paris, 1829.
[3] Sir E. Home, Lect. on Comp. Anat. iii. 315.

conducting it to the surface of the ovum; and that in order to succeed in these artificial fecundations, the sperm must be diluted; if too much concentrated its action is less. They satisfied themselves likewise, that the chief part of the sperm penetrates as far as the ova, as animalcules could be detected moving in the mucus covering their surface, and these animalcules, they conceive, are the active part of the sperm. It is not, however, universally admitted, that positive contact of sperm with the ovum is indispensable to fecundation. Some physiologists maintain, that the sperm proceeds no further than the upper part of the vagina; whence it is absorbed by the vessels of that canal, and conveyed through the circulation to the ovary. This is, however, the most improbable of all the views that have been indulged on this topic; for if such were the fact, impregnation ought to be effected as easily by injecting sperm into the bloodvessels,—the female being, at the time, in a state of voluptuous excitement. It has been directly overthrown, too, by the experiments of Dr. Blundell[1] on the rabbit, who found, that when the communication between the vagina and the uterus was cut off, impregnation could not be accomplished, although the animal admitted the male as often as fifty times, generally at intervals of two or three days or more. Yet it was evident that much of the male fluid had been deposited in the vagina, and absorbed by veins or lymphatics.[2] Bischoff[3] states, that he has frequently extirpated the uterus in rabbits, leaving the vagina and ovaries with the tubes; and in no case was the animal fecundated after the operation, although it admitted the male freely.

Others have presumed, that when the sperm is thrown into the vagina, a *halitus* or *aura—aura seminis*—escapes from it, makes its way to the ovary, and impregnates an ovum; whilst others, again, are of opinion, that the sperm is projected into the uterus, and in this cavity undergoes admixture with the germ furnished by the female; and a last class, with more probability in their favour, maintain, that the sperm is thrown into the uterus, whence it passes through the Fallopian tube to the ovary, by the fimbriated extremity of the tube embracing at the time the latter organ. The late Dr. Dewees[4] suggested, that after the sperm is deposited on the labia pudendi or in the vagina, it may be taken up by a set of vessels—which, he admitted, had never been seen in the human female—whose duty it is to convey it to the ovary. This conjecture, he conceived, had been in part confirmed by the discovery of ducts, leading from the ovary to the vagina, in the cow and sow, by Dr. Gartner, of Copenhagen. The objections that may be urged against his hypothesis, Dr. Dewees remarks, "he must leave to others." We have no doubt, that his intimate acquaintance with the subject could have suggested many that are pertinent and cogent. It will be obvious, that if we admit the existence of the ducts described by Gartner, it by no means follows, that they are inservient to the function in question.

[1] Principles and Practice of Obstetricy, Amer. edit., Washington, 1834.

[2] See the details of an experiment with a similar object by Harlan, Medical and Physical Researches, p. 627, Philad., 1835.

[3] Développement de l'Homme, &c., traduit par Jourdan, p. 20, Paris, 1843.

[4] A Compendious System of Midwifery, 7th edit., Philad., 1835.

Independently, too, of the objection, that they have not been met with in the human female, it may be urged, that if we grant their existence there would seem to be no reason, why closure of the os uteri after impregnation, or interruption of the vulvo-uterine canal by division of the vagina—as in the experiments of Dr. Blundell on rabbits—or division of the Fallopian tubes, should prevent subsequent conception,—in the first case during the existence of pregnancy,—in the last two for life. These vessels ought, in both cases, to continue to convey sperm to the ovary; and extra-uterine pregnancies or superfœtation ought to be constantly occurring.

MM. Prévost and Dumas,[1] and Dr. Ritchie,[2] are amongst the most recent writers, who maintain, that fecundation takes place in the uterus, and the former gentlemen assign the following reasons for their belief. *First.* In their experiments, they always found sperm in the cornua of the uterus, and they conceive it natural, that fecundation should be effected only where sperm is. *Secondly.* In animals, whose ova are not fecundated until after they have been laid, fecundation must necessarily be accomplished out of the ovary; and, *Thirdly.* In their experiments on artificial fecundation, they have never been able to fecundate ova taken from the ovary. In reply to the first of these positions it has been properly remarked by M. Adelon,[3] that the evidence of MM. Prévost and Dumas with regard to the presence of sperm elsewhere than in the uterus is only of a negative character; and that, on the other hand, we have the positive testimony of physiologists in favour of its existence in the Fallopian tubes and ovary. Haller asserts, that he found it there; and MM. Prévost and Dumas afford us evidence against their position respecting the seat of fecundation. They affirm, that on the first day after copulation, sperm was discoverable in the cornua of the uterus, and it was not until after the lapse of twenty-four hours, that it had attained the summits of the cornua. Once they detected it in the Fallopian tubes;—a circumstance, which is inexplicable under the view, that fecundation is accomplished in the uterus. Leeuenhoek and Hartsöker, also, found it in some cases in the Fallopian tube; and Bischoff, Wagner,[4] and Dr. M. Barry,[5] discovered spermatozoids in the fluid collected from the surface of the ovary, and within the capsular prolongations of the Fallopian tubes that enclose the ovaria. Still more recently, Dr. Barry,[6] in two cases, found spermatozoids within an ovum of the rabbit taken from the Fallopian tube. They were within the thick transparent membrane—*zona pellucida*—brought with the ovum from the ovary. M. Pouchet,[7] however, whilst he gives delineations of spermatozoids found in the middle of the Fallopian tubes of a rabbit on the surface of an ovum fifteen hours after copulation, denies that in the mammalia the sperm can ascend to the ovary. The contractions of the tubes; their ciliary movements; the capillarity of the ducts, and the impassable mucus (*mucus infranchissable*) he regards

[1] Annales des Sciences Naturelles, iii. 113.
[2] Lond. Med. Gazette, cited in Amer. Journ. of the Med. Sciences, Jan., 1846, p. 187.
[3] Physiologie de l'Homme, 2de édit., iv. 68, Paris, 1829.
[4] Elements of Physiology, translated by Dr. R. Willis, p. 66, Lond., 1841.
[5] Philosophical Transactions for 1839, p. 315.
[6] Proceedings of the Royal Society, Dec. 8, 1842.
[7] Théorie positive de l'Ovulation spontanée, Atlas, Planche xv. fig. 9, Paris, 1847.

as invincible impediments; and maintains categorically,—or, to employ the language of M. Raciborski,[1] cited by M. Pouchet, himself, "with a vigour and energy of dialectics hitherto unused in science," that "even if it could reach the germiferous organ, it assuredly could not traverse the thick coats, which protect the ovules and arrive at them."[2] He believes, moreover, that observers must have taken for spermatozoids on the ovary certain moving bodies, which he calls *pseudo-zoospermes*, and which, he says, can only be either microscopic entozoa, or the extremities of certain of the digitations, which form the fimbriated extremity of the Fallopian tube,—more probably the latter.[3] He admits, however, that it seems to be almost certain, that these *pseudo-zoospermes* are exactly the same bodies as were seen by M. Donné[4] on the nasal mucous membrane of a man. M. Donné observed epithelial shreds of this membrane separate spontaneously into minute conical portions, each of which had its own movement, like that of the spermatozoids; and we have elsewhere shown,—contrary to the opinion of M. Pouchet,—that the spermatozoids themselves are not perhaps entitled to any higher rank than that of ciliated epithelial cells.

In reply to the second argument, it may be remarked, that analogies drawn from inferior animals are frequently loose and unsatisfactory; and ought, consequently, to be received with caution. This is peculiarly one of those cases; for fecundation, in many animals, is always accomplished *out* of the body; and analogy might with equal propriety be invoked to prove, that in the human female the same thing must occur. Moreover, in certain oviparous animals—as in the common fowl—a single intercourse with the male may fecundate all the eggs she may lay in a season. In answer to the third negative position of MM. Prévost and Dumas, the positive experiments of Spallanzani may be cited, who succeeded in producing fecundation in ova that had been previously separated from the ovary.

The evidence that conception—as the rule—takes place in the ovary, appears to be convincing. Ovarian pregnancy offers proof of it. Of this, Mr. Stanley, of Bartholomew's Hospital, has given an instructive example;[5] and a still more extraordinary one is related by Dr. Granville.[6] Other varieties of extra-uterine pregnancy are confirmative of the same position. At times, the fœtus is found in the cavity of the abdomen,—the ovum seeming to have escaped from the Fallopian tube when its fimbriated extremity

Fig. 389.

Tubal Pregnancy.

[1] De la Puberté et de l'Age Critique, p. 519, Paris, 1844.
[2] Op. cit., p. 449.
[3] Op. cit., p. 416.
[4] Cours de Microscopie, p. 175, Paris, 1844.
[5] Medical Transactions, vol. vi.
[6] Philosophical Transactions for 1820.

grasped the ovary to receive and convey it to the cavity of the uterus. At other times, the fœtus is developed in the Fallopian tube,—as in the marginal figure (Fig. 389),—some impediment having existed to the passage of the ovum from the ovary to the uterus. This impediment can be excited artificially, so as to give rise to tubal pregnancy. Nuck applied a ligature around one of the cornua of the uterus of a bitch, three days after copulation; and found, afterwards, two fœtuses arrested in the Fallopian tube between the ligature and ovary. Von Baer[1] detected an ovule in its passage along the Fallopian tube in a bitch; and Raspail asserts, that he once met with an ovule still attached to the ovary, which contained an embryo.[2]

It is obvious, then, from these facts, either that fecundation occurs in the ovarium, or else that the ovum, when fecundated in the uterus, travels along the Fallopian tube to it; and thence back again to the uterus, which is not probable. It has been said, indeed, that ovarian and tubal pregnancies are exceptions to the rule; but no adequate evidence has been afforded of this. They certainly establish, that fecundation does take place in the ovary, and we are in want of positive, well authenticated cases of its having been accomplished elsewhere.

But, to prevent impregnation, it is not necessary that the ovaries should be removed. It is sufficient to deprive them of all immediate communication with the uterus, by simply dividing the Fallopian tubes. On this subject, Dr. Haighton[3] instituted numerous experiments, the result of which was, that after the operation a fœtus was in no instance produced. The operation is much more simple than the ordinary method of spaying by the removal of the ovaries, and it has been successfully practised, at the recommendation of the author, on the farm of his friend Thomas Jefferson Randolph, Esq., of Virginia. Simple division of the Fallopian tubes does not take away the sexual desire, as Haighton supposed; for the ovaries are still existent; but if they be removed, all desire is lost. A case is detailed of a natural defect of this kind in an adult woman, who had never exhibited the slightest desire for commerce with the male, and had never menstruated. On dissection, the ovaria were found deficient; and the uterus was not larger than an infant's.[4] Dr. Blundell has proposed the division of the tubes, and even the removal of a small portion of them, so as to render them completely impervious, when the pelvis is so contracted as not to admit of the birth of a living child in the seventh month; and he goes so far as to affirm, that the operation is much less dangerous than delivery by perforating the head, when the pelvis is greatly contracted.

We have already remarked, that sperm has been found in the cavity of the uterus, and even in the Fallopian tubes. Fabricius ab Acquapendente maintained, that it could not be detected there; and Harvey contended, that in the case of the cow, whose vagina is very long, as well as in numerous other animals, it cannot possibly reach the uterus, and that there is no reason for supposing it ever does. In addition, however, to the facts already cited, we may remark, that Mr. John

[1] De Ovi Mammalium et Hominis Genesi, Lips., 1827.
[2] Chimie Organique, p. 262, Paris, 1833.
[3] Philosoph. Transact. for 1797.
[4] Philosoph. Transact. for 1805.

Hunter[1] killed a bitch in the act of copulation, and found the semen in the cavity of the uterus, conveyed thither, in his opinion, *per saltum.* Ruysch[2] discovered it in the uterus of a woman taken in adultery by her husband and killed by him; and Haller[3] in the uterus of a sheep killed forty-five minutes after copulation. An interesting case, in relation to this point, was published by Dr. Henry Bond,[4] of Philadelphia. A young woman, after having passed a part of the night with a male friend, destroyed herself early in the morning, by taking laudanum. On cutting open the uterus, it was found to be thickly coated with a substance having the appearance, and strong peculiar odour, of sperm. One of the Fallopian tubes was laid open, and found to contain apparently the same matter; but it was not ascertained whether it possessed the seminal odour. More recently, Bischoff,[5] in his investigations, found few or no spermatozoids in the vagina of bitches and rabbits, after coitus; but the uterus was quite full of them.

Blumenbach[6] supposes, that, during the venereal orgasm, the uterus sucks in the sperm. It is impossible to explain the mode in which this is accomplished, but the fact of the entrance of the fluid into that organ, and even as far as the ovarium, seems unquestionable. This Dr. Blundell[7] admits, but he is disposed to think, that, in general, the rudiments from the mother and the fecundating fluid meet in the uterus; as, in his experiments on rabbits, he found—from the formation of corpora lutea, the developement of the uterus, and the accumulation of water in the uterine cavity—that the rudiments may come down into the uterus, without a previous contact with the sperm. His experiments, however, appear to prove nothing more, than that infecund ova may be discharged from the ovarium; and that if they are prevented from passing externally, owing to closure of the vagina or cervix uteri, the uterine phenomena alluded to may occur. They do not invalidate the arguments already brought forward to show, that the ovum must be fecundated in the ovarium.

It has been suggested by Dr. Bostock,[8] that the ciliary motions, which have been observed by Purkinje, Valentin,[9] and others, on the mucous membrane of the air-passages, and likewise on that of the generative organs, and whose office appears to be to propel substances along them, may have something to do with the propulsion of the sperm towards the ovary; and J. Müller[10] affirms, that "the mode in which the semen is conducted so far through the female generative organs, is no longer a problem, requiring solution; for the discovery of the ciliary motion affords a

[1] Philosoph. Transact. for 1817.
[2] Thesaur. Anat. iv.; and Adversaria Anat. Med.-Chirurg., Dec. 1.
[3] Element. Physiol, viii. 22.
[4] American Journal of the Medical Sciences, No. xxvi., for February, 1831, p. 403.
[5] Entwickelungsgeschichte des Kaninchen-Eies, u. s. w., Leipz., 1842; cited by Mr. T. W. Jones, in Brit. and For. Med. Rev., Oct., 1843, p. 513; and Op. cit.
[6] Elements of Physiology, by Elliotson, 4th edit., p. 467, Lond., 1828. See, also, Günther, Untersuchungen und Erfahrungen, Hannover, 1837, cited by Bischoff.
[7] Principles, &c., of Obstetricy, Amer. edit., p. 56, Washington, 1834.
[8] Physiology, 3d edit., p. 654, Lond., 1836.
[9] Müller's Archiv., B. i.; and translation in Dublin Journal of Med. Science, May, 1835; and in Edinb. New Philos. Journal, for July, 1835.
[10] Elements of Physiology, translated by Baly, p. 1491, Lond., 1842.

solution of it." Dr. Sharpey,[1] however, remarks, that the direction of these motions is from within outwards, so that he conceives it to be difficult to assign any other office to them than that of conveying outwards the secretion of the membrane; unless we suppose that they also bring down the ovum into the uterus. Prof. Wagner[2] considers, that the sperm reaches the ovary, partly by ciliary motion, which begins in the cervix uteri, partly by the contraction of the tubes, and partly by the motility of the spermatozoids; whilst Dr. Carpenter[3] thinks it not unreasonable to suppose, that the last is the sole power; and that the transit of the spermatozoids from the vagina to the ovaries is effected by the same kind of action as that which causes them to traverse the field of the microscope. We have seen, however, that not only spermatozoids, but sperm itself, have been found in the uterus and Fallopian tubes. Future observations may shed farther light on this obscure subject.

When treating of the views recently embraced by many physiologists as to the ovarian cause of menstruation, it was stated, that conception has been believed to be more easy during menstruation, or immediately before, or immediately after. Some, indeed, as M. Pouchet,[4] have asserted, in the absence of adequate numerical evidence, the dangerous doctrine, that the aptitude scarcely exists at the middle of the interval between two menstrual periods, although there are numerous facts to show, that fecundation occurs in intermenstrual periods.[5] M. Coste[6] affirms, that the Morgue of Paris has, for years, yielded him many opportunities for establishing this. The generality of those physiologists believe, that it is not necessary for the fecundating material of the male to come in contact with the ovum in the ovarium—although in the vegetable, which is often taken as the analogue, such contact is known to be indispensable. They believe, that after an ovum has escaped, it may meet and be acted upon by the male sperm, either in the Fallopian tubes or in the uterus; and some think, notwithstanding the facts already mentioned of ovarian pregnancy, and of spermatozoids having been found in the ovary, that neither the sperm nor any part of it can reach the ovary, and therefore impregnation can never be effected in it. A recent writer[7] considers it most probable, that in the human female, as well as in the females of animals, the desire for sexual intercourse is greatest at the menstrual period "or heat," especially towards the decline of the discharge; at which latter period, he says, from observation on animals, it is proved, that ova are usually discharged. Bitches, he says, are generally observed to be languid, and to refuse the male during the first few days of heat; but after this they become lively, and readily admit of being lined; and analogous to

[1] Art. Cilia, Cyclop. of Anat. and Physiology, part vii. p. 633, July, 1836.
[2] Elements of Physiology, translated by R. Willis, part i., p. 72, Lond., 1841.
[3] Principles of Human Physiology, 2d edit., p. 689, Lond., 1844; and Elements of Physiology, Amer. edit., p. 456, Philad., 1846.
[4] Théorie positive de la Fécondation des Mammifères, Paris, 1842; Bulletin de l'Académie, Jan., 1845, p. 64; and especially his Théorie positive de l'Ovulation spontanée, &c., 9ème Loi, p. 170, Paris, 1847.
[5] Ritchie, op. cit.
[6] Op. cit., p. 203.
[7] Girdwood, in London Lancet, Dec. 7 and 14, 1844.

this is the indisposition of the human female during the early part of each menstrual period, previous to the discharge becoming fully established. It could be understood, that a fecundating copulation might occur in the last days of menstruation, and perhaps soon after its cessation, through the male sperm coming in contact with an ovum separated from the ovary, and in the Fallopian tubes, or uterus;—for we are told authoritatively, by M. Pouchet,[1] it is a "law," that, in the mammalia, fecundation never occurs unless the emission of ova coincides with the presence of seminal fluid, although the menstrual secretion itself—it might be presumed—would tend rather to throw out of the body the fecundating material; but if, as elsewhere said, and generally believed, fecundation *often* occurs a short time before menstruation, then the ovum could not have left the ovary,—if the facts above cited be correct,—and impregnation must have been effected in it. In the existing state of knowledge, then, this organ appears to be the seat of fecundation,—although the author is not disposed to assert, that it *cannot* be accomplished at the time of, or soon after, the escape of the ovum from the ovarium.

By many modern writers on the ovular theory of menstruation, it is maintained that a period of about eight days is needed for the passage of the unimpregnated ovum from the ovarium to the uterus, and its discharge from the female; M. Pouchet,[2] however,—according to whose "tenth fundamental law," in the human species and the mammalia, the ovum and the sperm meet normally in the uterus, or in the portion of the Fallopian tubes near it, and there fecundation is accomplished—extends the time much beyond this. His view is, that in the human species, a vesicle of De Graaf is torn normally at each menstruation, which spontaneously discharges its contained ovule either immediately afterwards, or within the first four days following. A period of from two to six days is generally required for it to clear the tube, and it is subsequently retained in the uterus for from two to six days by the decidua. "If"—he adds—"during the time of its translation and sojourn in the genital apparatus—that is, during the first twelve days that follow menstruation, and rarely up to the fourteenth day—there is sexual intercourse, fecundation may take place; but it can never be effected at a later period, because the ovum must manifestly have been dragged out by the decidua."

It is an overwhelming objection, however, to these views, that the Jewish women are bound to observe abstinence from sexual intercourse for eight days; and it is affirmed by Dr. Girdwood,[3] that "it is the custom amongst Jews, who are scrupulous, for the wife to retire from the society of her husband for a period of *thirteen* days reckoning from the first day of being 'nyddar;'—that is to say, by those who are strict, five days are kept, as prescribed by the Rabbinical law (for the purpose of making security doubly sure) in addition to the eight days enforced by the law of Moses," and he adds "as a fact, that in general, among this singular people, no female is found to be a mother before

[1] Théorie Positive de l'Ovulation, &c., p. 209. [2] Op. cit., p. 297 and p. 467.

[3] Appendix to W. Tyler Smith, Parturition and the Principles and Practice of Obstetrics, Amer. edit., p. 386, Philad., 1849.

at least nine calendar months and a half have elapsed,"—whence, he infers, that fecundation must have taken place immediately *before* the catamenial period. How fatal are such facts, observed on a large scale, to the dangerous doctrine of M. Pouchet and others, that intercourse cannot prove fecundating after twelve or fourteen days from the separation of the ovule from the ovary, especially when it is borne in mind, that the Jewish women are celebrated for being prolific. One single well observed antagonistic case would, indeed, be sufficient to disprove it, and such a one, recorded by Dr. Montgomery, of Dublin, is referred to hereafter, under the head of Duration of Pregnancy. In that case, the last menstruation occurred on the 18th of October; and the fecundating intercourse took place on the 10th of November, or twenty-three days afterwards.[1] The case referred to by Dr. Dewees under the same head is equally opposed to the presumption. Moreover, from the data afforded by MM. Pouchet and Raciborski, M. Coste infers, that "there is not in the entire month a single moment in which the emission of ova and impregnation are impossible."[1]

Granting that conception occurs in the ovarium, and that sperm is projected into the uterus, with or without the actions referred to; in what manner does the sperm exert its fecundating agency on the ovarium? It is manifestly impossible, that the force of projection from the male can propel it not only as far as the cornua of the uterus but also through the narrow media of communication between the uterus and ovary by the Fallopian tubes. This difficulty suggested the idea of the *aura seminis* or *aura seminalis*, which, it was supposed, might readily pass into the uterus, and through the tubes to the ovary. Dr. Haighton, indeed, embraced an opinion more obscure than this, believing, that the semen penetrates no farther than the uterus, whence it acts on the ovaria by sympathy;—and this obscure view has been adopted by some distinguished individuals.

In opposition to the notion of the *aura seminis*, we have some striking facts and experiments. In all those animals, in which fecundation is accomplished out of the body, direct contact of the sperm appears necessary. Spallanzani, and MM. Prévost and Dumas found, in their experiments on artificial fecundation, that they were always unsuccessful when they simply subjected ova to the emanation from sperm. Spallanzani took two watch-glasses capable of being fitted to each other, the concave surface of the one being opposed to that of the other. Into the lower he put ten or twelve grains of sperm, and into the upper about twenty ova. In the course of a few hours the sperm had evaporated, so that the ova were moistened by it; yet they were not fecundated; but fecundation was readily accomplished by touching them with the sperm that remained in the lower glass. A similar experiment was performed by MM. Prévost and Dumas. They prepared about an ounce and a half of a fecundating fluid from the expressed humour of twelve testicles, and as many vesiculæ seminales. With two and a half drachms of this fluid they fecundated more than two hundred ova. The remainder of the fluid was put into a small retort,

[1] Histoire générale et particulière du Développement, &c., p. 199, Paris, 1847.

to which an adopter was attached. In this, forty ova were placed, ten of which occupied the hollowest part, whilst the rest were placed near the beak of the retort. The apparatus was put under the receiver of an air-pump, and air sufficient was withdrawn to diminish the pressure of the atmosphere one-half. The rays of the sun were now directed upon the body of the retort, until the temperature within rose to about 90°; and after the lapse of four hours, the experiment was stopped; and the following were the results. The eggs at the bottom of the adopter were bathed with a transparent fluid, the product of distillation. They had become tumid, as in pure water, but had undergone no developement. The eggs near the beak of the retort were similarly circumstanced, but all were readily fecundated by the thick sperm that remained at the bottom of the retort. No aura, nor emanation from the sperm, consequently, appeared to be capable of impregnating the ova. Absolute contact was indispensable. This is probably the case with the human female, and if so, the sperm must proceed from the uterus along the Fallopian tube to the ovarium. The common opinion is, that during the intense excitement at the time of copulation, the tube is raised, and its digitated extremity applied to the ovary. The sperm then proceeds along it,—in what manner impelled we know not,—and attains the ovary. According to Dr. Blundell and others, during the time of intercourse, the whole of the tube is in a state of spontaneous movement. Mr. Cruikshank pithed a female rabbit, when in heat, and examined the uterine system minutely. The external and internal parts of generation were found black with blood; the Fallopian tubes were twisted like writhing worms, and exhibited a very vivid peristaltic motion; and the fimbriæ embraced the ovaries—like fingers laying hold of an object—so closely and firmly as to require force, and even slight laceration to disengage them. Haller states, that by injecting the vessels of the tube in the dead body, it assumed this kind of action. De Graaf, too, affirms, that he has found the fimbriated extremity adhering to the ovary, twenty-seven hours after copulation; and M. Magendie has seen the extremity of the tube applied to a vesicle.

As excitement of some form would appear to be necessary to cause the digitated extremity of the tube to embrace the ovary, it would seem probable, that a female could not be impregnated without some consciousness of sexual union. This may be imperfect, as during sleep, or when in a state of stupor—either from spirituous liquors or narcotics—but still some impression must be made in order that fecundation may take place. It would not seem to be necessary, however, that the excitement should be venereal, or perhaps appreciated by the brain, inasmuch as when infecund ova pass from the ovaries into the tubes, as during menstruation, the same application of the fringed extremities of the tubes to the ovary probably takes place. This may be owing to a reflex action commencing in the uterus or ovary.

As the aura seminis appears to be insufficient for impregnation, it is obviously a matter of moment, that the sperm should be projected as high up the vagina as possible. It has been often observed, that where the orifice of the urethra does not open at the extremity of the glans, but beneath the penis, or at some distance from the point, the individual

has been rendered less capable of procreation. In two cases, that fell under the care of the author, the urethra was opened opposite the corona glandis by a sloughing syphilitic sore; and the aperture continued, in spite of every effort to the contrary. The individuals were married, and the fathers of three or four children; but after this occurrence they had no increase of their families. Many medico-legal writers have considered, that when the urethra terminates at another than its natural situation, impotence is the necessary result,—and that although copulation may be effected, impregnation is impracticable. Zacchias,[1] however, gives a case to the contrary. M. Belloc,[2] too, asserts, that he knew of a person, in whom the orifice of the urethra terminated at the root of the frænum, who had four children that resembled the father, two having the same malformation; and Dr. Francis refers to the case of an inhabitant of New York, who, under similar circumstances, had two children. Many such cases, are, indeed, on record.[3] We cannot, therefore, regard it as an absolute cause of impotence; but the inference is just, that if the semen be not projected far up the vagina, and in the direction of the os uteri, impregnation is not likely to be accomplished; a fact, which it might be of moment to bear in mind, where the rapid succession of children is an evil of magnitude. Yet, notwithstanding this weight of evidence, it has been affirmed by Professor Heim,[4] that impregnation may take place by the simple contact of sperm with the lower part of the abdomen. The answer to this view, by M. D'Outrepont,[5] appears, however, overwhelming. Heim relies on statements made by the parties that no penetration existed; but M. D'Outrepont properly observes, that whenever this has been alleged in a case of pregnancy, he has found, if the parties were strictly questioned, that one or both of them admitted, that the male organ *might* have been in the vagina, or at least in the vulva.

The part, then, to which sperm is applied is the ovary, and perhaps the liquor seminis is the substance that passes through the parietes of the follicle by imbibition, in order to reach the ovum. Mr. T. W. Jones[6] states, that although he is not prepared to deny this; yet, when he takes into consideration all the evidence on the subject, he is of opinion, that there is no proof, that fecundation takes place until the ovum has escaped from the Graafian follicle, and comes into direct contact with the sperm. Bischoff and Wagner[7] were until recently of opinion, that fecundation is accomplished by the liquor sanguinis; but the latter now considers the view to be less admissible than he did formerly; urging, amongst other reasons, that a liquor seminis is positively not traceable in many, especially of the lower, animals,—as worms, insects, &c.,—

[1] Quæstiones Medico-Legales, Lugd., 1674.

[2] Cours de Médecine Légale, p. 50, Paris, 1819.

[3] Beck's Elements of Medical Jurisprudence, 6th edit., p. 71, Philad., 1838.

[4] Wochenschrift für die Gesammte Heilkunde; and Gazette Médicale, Sept. 25, 1836.

[5] Neue Zeitschrift für Geburtskunde, von Busch, d'Outrepont und Ritgen, B. iv. H. ii., Berlin, 1836; cited in Amer. Med. Intelligencer, p. 275, Nov. 1, 1837.

[6] Report on the Ovum of Man and the Mammifera, in Brit. and For. Med. Rev., Oct. 1843, p. 525.

[7] Elements of Physiology, by R. Wallis, p. 74, Lond., 1844.

the whole mass of the sperm being formed by spermatozoids alone; but this, we think, may well be questioned. He urges further against the idea of the liquor seminis being the agent in fecundation, that its action on the ova would be impossible in many cases,—for instance, where fecundation takes place in water without any real act of copulation,—the sperm being ejected, and left to chance as to whether it may come in contact with ova or not.[1] Bischoff, too, has abandoned his former opinion, and now maintains, that "spermatozoids and ova are constituents of an organism;" and that a positive contact of the two is necessary for the formation of a new being.[2]

Let us now inquire into the changes experienced by this body after a fecundating copulation. Fabricius, of Acquapendente,[3] having killed hens a short time after they had been trodden, examined their ovaries, and observed,—amongst the small yellow, round granules, arranged racemiferously, which constitute those organs,—one having a small spot, in which vessels had become developed. This increased in size, and was afterwards detached, and received by the oviduct; becoming covered, in its passage through that tortuous canal and the cloaca by particular layers, especially by the calcareous envelope; and being ultimately extruded in the form of an egg. Harvey,[4] in his experiments on the doe, made similar observations. He affirms, positively, that the ovary furnishes an ovum, and that the only difference, which exists amongst animals in this respect, is, that in some the ovum is hatched after having been laid; whilst in others it is deposited in a reservoir—a womb—where it undergoes successive changes. De Graaf[5] instituted several experiments on rabbits for the purpose of detecting the series of changes in the organs from conception till delivery. Half an hour after copulation, no alteration was perceptible, except that the cornua of the uterus appeared a little redder than usual. In six hours, the coverings of the ovarian vesicles seemed reddish. At the expiration of a day from conception, three vesicles in one of the ovaries, and five in the other, appeared changed, having become opaque and reddish. After twenty-seven, forty, and fifty hours, the cornua of the uterus and the tubes were very red, and one of the tubes had laid hold of the ovary; a vesicle was in the tube, and two in the right cornu of the uterus. These vesicles were as large as mustard seed. They were formed of two membranes, and were filled by a limpid fluid. On the fourth day, the ovary contained only a species of envelope, called, by De Graaf, a *follicle;* this appeared to be the capsule that had contained the ovum. The ovum itself was in the cavity of the uterus; had augmented in size, and its two envelopes were very distinct. Here it remained loose until the seventh day, when it formed an adhesion to the uterus. On the ninth day, De Graaf observed a small opaque point, a kind of cloud, in the transparent fluid that filled the ovum. On the tenth day, this point had the shape of a small worm. On the eleventh, the embryo was clearly perceptible; and from this period, it underwent its full developement, until the thirty-first day, when de-

[1] Art. Semen, Cyclopædia of Anat. and Physiology, Pt. xxxiv. p. 507, Lond., Jan. 1849.
[2] Müller's Archiv. für Anatom., No. v. p. 441, Berlin, 1847.
[3] Opera., Lips.
[4] De Generatione, p. 228.
[5] Tom. i. 310.

livery took place. Malpighi[1] and Vallisnieri[2] also observed, in their experiments, that after a fecundating copulation, a body was developed at the surface of the ovary, which subsequently burst, and suffered a smaller body to escape. This was laid hold of by the tube, and conveyed to the uterus. It is not, however, universally admitted, that this body is the impregnated ovum; some affirming, that it is a sperm similar to that of the male; and others, that it is an amorphous substance, which, after successive developements, becomes the new individual.[3]

Haller exposed the females of sheep and other animals to males on the same day, and killed them at different periods after copulation, for the purpose of detecting the whole series of changes by which the vesicle is detached from the ovary and conveyed to the uterus. Half an hour after copulation, one of the vesicles of the ovary appeared to be prominent; to have on its convexity a red, bloody spot, and to be about to break; in an hour or more, the vesicle gave way, and its interior seemed bleeding and inflamed. What remained of the vesicle in the ovary, and appeared to be its envelope, gradually became inspissated, and converted into a body of a yellowish colour, to which he gave the name *corpus luteum.* The cleft, by which the vesicle escaped, was observable for some time; but, about the eighth day, it disappeared. On the twelfth day, the corpus luteum became pale, and began to diminish in size. This it continued to do until the end of gestation; and ultimately became a small, hard, yellowish or blackish substance, which could always be distinguished in the ovarium by the cicatrix left by it. Its size was greater, the nearer the examination was made to the period of conception. In a bitch, for example, on the tenth day, it was half the size of the ovary; yet it proceeded, in that case, from one vesicle only. In multiparous animals, as many *corpora lutea* existed as fœtuses.

The experiments of Haller[4] have been frequently repeated with similar results. M. Magendie,[5] whose trials were made on bitches, observed, that the largest vesicles of the ovary were greatly augmented in size, thirty hours after copulation; and that the tissue of the ovary surrounding them had acquired greater consistence; changed colour, and become of a yellowish-gray. This part was the *corpus luteum.* It, as well as the vesicles, increased for the next three or four days; and seemed to contain, in its areolæ, a white, opaque fluid, similar to milk. The vesicles now successively ruptured the external coat of the ovary, and passed to the surface of the organ, still adhering to it, however, by one side. Their size was sometimes that of a common hazelnut; but no germ was perceptible in them. The surface was smooth, and the interior filled with fluid. Whilst they were passing to the uterus, the corpus luteum in the ovary underwent the changes referred to by Haller.

1 De Formatione Pulli in Ovo, Lond., 1673; and De Ovo Incubato, Lond., 1686.
2 Istoria della Generazione dell'Uomo, Discorsi Academ., iv., Venez., 1722–1726.
3 Adelon, Physiologie de l'Homme, iv. 74.
4 Element. Physiologiæ, lib. xxix. sect. 1, Bern., 1766.
5 Précis de Physiologie, edit. citat., ii. 534.

In similar experiments, instituted by MM. Prévost and Dumas,[1] no change was perceptible in the ovary during the first day after fecundation; but, on the second, several vesicles enlarged, and continued to do so for the next four or five days, so that from being two or three millimètres in diameter, they were eight. From the sixth to the eighth day, the vesicles burst, and allowed an ovule to emerge, which often escaped observation, owing to its not being more than half a millimètre in diameter; but was clearly seen by MM. Prévost and Dumas by the aid of the microscope. This part they termed *ovule*, in contradistinction to that developed in the ovary, which they called *vesicle*. The latter had the appearance, on its surface, of a bloody cleft, into which a probe might be passed; and in this way it could be shown, that the vesicle had an interior cavity, which was the void space left by the ovule after its escape from the ovarium into the Fallopian tube. On the eighth day, in the bitch, the ovule passed into the uterus. All the ovules did not, however, enter that cavity at the same time,—an interval of three or four days sometimes occurring between them. When they attained the cavity, they were at first free and floating; and if examined with a microscope magnifying twelve diameters, seemed to consist of a small vesicle, filled with an albuminous, transparent fluid. If examined in water, their upper surface had a mammiform appearance, with a white spot on the side. This was the *cicatricula*. These ovules speedily augmented in size, and, on the twelfth day, fœtuses could be recognised in them.

Similar experiments, with like results, were made by Von Baer,[2] Seiler,[3] and others; and much minute attention has been paid to the subject by recent histologists,—by Wagner, Barry, Bischoff, T. W. Jones, Pouchet and Coste, more especially. As regards the ovarian changes, Wagner affirms, that after a fecundating intercourse, an increased flow of blood takes place to the ovaries; the vascular membrane of the Graafian vesicle enlarges; the granules mingled with its contents become greatly developed, and changed; and thickening and general increase of its walls, particularly of the base and sides, supervene; the ovum and other contents of the follicle are by this pressed forwards, or against that aspect of the follicle, which is in contact with the peritoneum, and which now becomes thinner and thinner, and finally bursts, so that the ovum escapes, and a cavity is left in the ovary, which is soon obliterated by the growth on all sides of the inner membrane of the follicle; a reddish, fleshy-looking mass sprouts from the walls towards the shrinking cavity, and the rent by which the ovum had escaped is finally closed. The follicle, thus altered, constitutes the *corpus luteum*. This is the generally received opinion, and it is analogous to that long since entertained by Haller. The outer layer of the Graafian follicle is considered to be of a fibrous structure, and therefore more elastic than the internal, whose structure is cellulo-vascular. The former, therefore, contracts more; and the latter being intimately united with it follows its movement, and consequently becomes thrown into folds or

[1] Annales des Sciences Naturelles, iii. 135.
[2] De Ovo Mammalium, &c., Epist., Lips., 1827.
[3] Das Ei und Die Gebärmutter des Menschen, Dresd., 1832.

wrinkles, which project into the cavity: at the same time, according to M. Coste,[1] it becomes hypertrophied, and a plastic secretion takes place into the cavity, which unites the folds together and is the blastema in the filling up of the follicle. The cicatrix left by the aperture in the follicle through which the ovum has escaped differs in form in different animals. In the human female it is an irregular and generally stelliform cleft.—But the corpus luteum will receive further attention presently.

From the above facts, then, we may conclude, that the effect of fecundation is to excite the vesicles in the ovaries to developement; that the ova, within the germinal part, burst their covering; are laid hold of by the Fallopian tube, and conveyed to the uterus, where they remain during the period of gestation.

In the passage of the ova along the Fallopian tube it has generally been believed, that they experience but little change. They carry off, according to Wagner, a small portion of the granular stratum of the vesicle with them, which appears hanging to them at first as an irregular, ragged, discoidal appendage; but this is soon detached. The ovum gains a little in size; but there is still no trace of any special spot where the embryo originates. It would seem, however, from the researches of British embryologists, that the outer membrane of the ovum, which it acquired in the ovary, becomes swollen with moisture in the tube, and assumes the appearance of a thick, gelatinous-looking membrane, formed probably by cells—the proper *chorion;* and by and by, the zona pellucida having disappeared, the newly formed chorion comes to be the only investment of the yolk. All the observations on the ovum in the Fallopian tubes have, however, been made on animals. Of the human ovum whilst in the tubes, little or nothing is known.

The exact time, required by the ovum or ova to make their way into the uterus, has not been accurately determined. Mr. Cruikshank[2] found, that in rabbits forty-eight hours were necessary. Dr. Haighton[3] divided one of the Fallopian tubes in a rabbit; and, having exposed the animal to the male, he observed that gestation occurred only on the sound side. On making this section after copulation, he found, that if it were executed within the first two days, the descent of the ovules was prevented; but if it were delayed for sixty hours, the ovules had passed through the tube and were in the cavity of the uterus. A case is quoted by writers on this subject, on the authority of a surgeon named Bussières, who observed an ovoid sac, about the size of a hazelnut and containing an embryo, half in the Fallopian tube and half adherent to the ovary.[4] The minuteness of the calibre of the Fallopian tube is not as great a stumbling-block in the way of understanding how this passage is effected as might appear at first sight. The duct is, doubtless, extremely small in the ordinary state; but it admits of considerable dilatation. M. Magendie[5] asserts, that he once found it half an inch in

[1] Histoire Générale et particulière du Développement des Corps organisés, p. 249, Paris, 1849; and Baly and Kirkes, Recent Advances in the Physiology of Motion, Senses, Generation and Developement, p. 52, Lond., 1848.

[2] Philosoph. Transactions for 1797.

[3] Ibid., lxxxvii. 304.

[4] Adelon, Physiologie de l'Homme, edit. cit., iv. 78.

[5] Précis, &c., edit. cit., p. 535.

diameter; and the size of the ovum, we have seen, is only $\frac{1}{200}$th part of an inch.

The period that elapses between a fecundating copulation and the entrance of the ovum into the uterus is different in different animals. In sheep, according to Haller[1] and Kuhlemann,[2] it occurs on the seventeenth day. In rabbits, it is uncertain, but occurs generally on the third or fourth day after copulation;[3] in bitches on the fifth, according to some, but not till after the lapse of ten or twelve days, according to others; and in the human female, perhaps about the same time; yet Mr. Burns infers from analogical evidence, that we should be more justified in the belief, that the ovum, in the human female, does not enter the uterus until at least three weeks after conception.[4] M. Maygrier refers to a case of abortion twelve days after copulation; the abortment consisting of a vesicle, shaggy on its surface, and filled by a transparent fluid. A case that has by many been considered one of the most instructive that we possess on this subject is given by Sir Everard Home,[5] and although, as Dr. Granville[6] has remarked, it has lately been the fashion to doubt its accuracy, or to esteem it morbid, there is not sufficient reason, perhaps, to discard it, more especially as Mr. Bauer's microscopic examination of the ovule, and description of its structure correspond with the more recent discoveries of Professor Boer. A servant-maid, twenty-one years of age, had been courted by an officer, who had promised her marriage, in order that he might more easily accomplish his wishes. She was but little in the habit of leaving home, and had not done so for several days, when she requested a fellow-servant to remain in the house, as she was desirous of calling upon a friend, and should be detained some time. This was on the 7th of January, 1817. After an absence of several hours, she returned with a pair of new corsets, and other articles of dress which she had purchased. In the evening she got one of the maidservants to assist her in trying on the corsets. In the act of lacing them, she complained of considerable general indisposition, which disappeared on taking a little brandy. Next day, she was much indisposed. This was attributed to the catamenia not having made their appearance, although the period had arrived. On the following day, there was a wildness in her manner, and she appeared to suffer great mental distress. Fever supervened, which confined her to her bed. On the 13th, she had an epileptic fit followed by delirium, which continued till the 15th, when she expired in the forenoon. On making inquiries of her fellow-servants, many circumstances were mentioned, which rendered it highly probable, that on the morning of the 7th, when she was immediately on the point of menstruating, her lover had succeeded in gratifying his desires; and that she had become pregnant on that day; so that, when she died, she

[1] Element. Physiol., viii. 59.

[2] Observ. quædam circa Negotium Generationis in Ovibus fact, Gotting., 1753.

[3] Recherches sur la Génération des Mammifères par Coste, suivies de Recherches sur la Formation des Embryons, par Delpech et Coste, Paris, 1834.

[4] The Principles of Midwifery, &c., 3d edit., p. 132, Lond., 1814.

[5] Philosophical Transactions for 1807, p. 252; and Lectures on Comparative Anatomy, iii. 288, Lond., 1823.

[6] Graphic Illustrations of Abortion, &c., p. 7, Lond., 1834.

was in the 7th or eighth day of impregnation. Dissection showed the uterus to be much larger than in the virgin state; and considerably more vascular. On accurately observing the right ovarium, in company with Mr. Clift, Sir Everard noticed, upon the most prominent part of its outer surface, a small ragged orifice. This induced him to make a longitudinal incision in a line close to the orifice, when a canal was found leading to a cavity filled with coagulated blood, and surrounded by a narrow yellow margin, in the structure of which the lines had a zigzag appearance. The cavity of the uterus was then opened, by making an incision through the coats from each angle; and from the point where these incisions met, a third incision was continued down through the os uteri to the vagina. The os uteri was found completely blocked up by a plug of mucus, so that nothing could have escaped by the vagina; the orifices leading to the Fallopian tubes were both open, and the inner surface of the uterine cavity was composed of a beautiful efflorescence of coagulable lymph resembling the most delicate moss. By attentive examination, Sir Everard discovered a small, spherical, transparent body concealed in this efflorescence, which was the impregnated ovum. This was submitted to the microscopic investigations of Mr. Bauer, who made various drawings of it, and detected two projecting points, which were considered to mark out, even at this early period, and before the ovum was attached to the uterus, the seat of the brain and spinal marrow. [?]

This case—if admitted as a correct observation—shows, that an ovum had left the ovary, and was in the interior of the uterus, prior to the seventh or eighth day after impregnation. Weber and Von Baer, however, have each recorded a case in which there was an opportunity for examining the embryo, probably eight days after a fecundating copulation; but no ovum was detected either in the uterus or tube, and it must be admitted, that some of the best observers—as will be stated hereafter—do not consider that the ovum enters the uterus before the 10th or 12th day after it quits the ovary. On comparing the degree of advancement of the fœtus in the human ovum, as described by different observers, with that of the fœtus in the dog, cat, and sheep, at known periods, Dr. Allen Thomson[1] hazards the opinion, that it does not arrive in the uterus before the eleventh or twelfth day after conception: —Valentin, indeed, thinks, the twelfth or fourteenth day. From this discrepancy, amongst observers, it is manifest, that our knowledge on the matter is by no means definite.

But—it has been asked—is it a mere matter of chance, which of the ovarian vesicles shall be fecundated; or are there not some riper than the rest, that receive, by preference, the vivifying influence of the sperm? MM. Prévost and Dumas have shown, that such is the case with oviparous animals. They found, in their experiments, that not only were the vesicles of the ovaries of frogs of different sizes, but that the largest were always laid first, whilst the smallest were not to be deposited until subsequent years. In all animals, whose eggs were fecundated exter-

[1] Art. Generation, in Cyclop. of Anat. and Physiol., part xiii. p. 454, Feb., 1838.

nally, they seemed evidently prepared or maturated. We have, too, the most indubitable evidence that birds—although unquestionably virgins—may lay infecund eggs; and analogy would lead us to believe, that something similar may happen to the viviparous animal; a position which has been confirmed by direct observation.

In all cases in which an ovum has escaped, a cavity of course is left in the ovarium, which is filled up, in the manner already mentioned, by a growth from the Graafian follicle, which constitutes the *corpus luteum.*

Not longer ago than the year 1808, the existence of this body in the ovarium was held to be full proof of impregnation. In that year, Charles Angus, Esq., of Liverpool, England, was tried at the Lancaster Assizes, for the murder of Miss Burns, a resident of his house.[1] The symptoms previous to her decease, and the appearances observed on dissection, were such as to warrant the suspicion that she had been poisoned. The uterine organs were also found to be in such a state as to induce the belief, that she had been delivered a short time before her death, of a fœtus, which had nearly arrived at maturity. It was not, however, until after the trial, that the ovaria were examined in the presence of a number of physicians; when a *corpus luteum* was distinctly perceived in one of them. The uterus was taken to London, and shown to several of the most eminent practitioners; all of whom appear to have considered, that the presence of a *corpus luteum* proved the fact of pregnancy beyond a doubt. Such, indeed, is the positive averment of Haller,[2] an opinion which was embraced by Dr. Haighton,[3] who maintained, that they furnish "incontestable proof" of previous impregnation. It was this belief,—coupled with the fact, that division of the Fallopian tubes, in his experiments, prevented impregnation, whilst corpora lutea were found, notwithstanding, in the ovary,—which led him to the strange conclusion, that the semen penetrates no farther than the uterus, and acts upon the ovaria by sympathy.

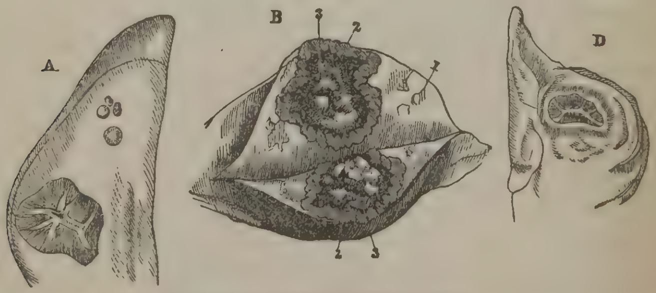
Sir Everard Home[4] affirmed, that corpora lutea exist independently of impregnation. "Upon examining," said he, "the ovaria of several women, who had died virgins, and in whom the hymen was too perfect to admit of the possibility of impregnation, there were not only distinct corpora lutea, but also small cavities around the edge of the ovarium, evidently left by ova, that had passed out at some former period;" and he affirms, that whenever a female quadruped is in heat, one or more ova pass from the ovaria to the uterus, whether she receives the male or not. This view of the subject appears to have been first propounded by Blumenbach,[5] who remarks that the state of the ovaria of females, who have died under strong sexual passion, has been found similar to that of rabbits during heat; and he affirms, that in the body of a young woman, eighteen years of age, who had been brought up in a convent, and had every appearance of being a virgin, Vallisnieri found five or

[1] Edinb. Med. and Surg. Journal, v. 220.
[2] Element. Physiolog., xxix. 1.
[3] Philosoph. Transact., lxxxvii. 159.
[4] Philosoph. Transact. for 1817 and 1819; and Lectures on Compar. Anat., iii. 304.
[5] Comment. Soc. Roy. Scient., Gotting., ix. 128; and Elliotson's edit. of Blumenbach's Physiology, 4th edit., p. 468, Lond., 1828.

six vesicles pushing forward in one ovarium, and the corresponding Fallopian tube redder and larger than usual, as he had frequently observed in animals during heat. Bonnet, he adds, gives the history of a young lady, who died vehemently in love with a man of low station, and whose ovaria were turgid with vesicles of great size; and similar facts have been recorded by numerous observers.[1] It has been already remarked, under Menstruation, that the periodical recurrence of that function has been supposed by some to consist in the production and developement of vesicles in the ovary; that is, of a matured ovum which is periodically brought forward either to be expelled with the menstrual flux, or to be destroyed in the genital organs.

Buffon, again, maintained, that instead of the corpus luteum of Haller being the remains of the ovule, it is its rudiment; and that the corpus exists prior to fecundation,—as he, also, found it in the virgin. Lastly, Dr. Blundell[2] states, that he had in his possession a preparation, consisting of the ovaries of a young girl, who died of cholera under seventeen years of age, with the hymen, which nearly closed the entrance of the vagina, unbroken. In these ovaries, the corpora lutea are no fewer than four; two of them being a little obscure, but easily perceptible by an experienced eye. The remaining two are very distinct, and differ from the corpus luteum of genuine impregnation merely by their more diminutive size and the less extensive vascularity of the contiguous parts of the ovary. "In every other respect," says Dr. Blundell, "in colour and form, and the cavity which they contain, their appearance is perfectly natural,—indeed, so much so, that I occasionally circulate them in the class-room, as accurate specimens of the luteum upon the small scale." Mr. Stanley[3] confirms the fact of the

Fig. 390.



Corpora Lutea of different periods.

B. Corpus luteum of about the sixth week after impregnation, showing its plicated form at that period. 1. Substance of the ovary. 2. Substance of the corpus luteum. 3. A grayish coagulum in its cavity; after Dr. Patterson. A. Corpus luteum, two days after delivery. D. In the twelfth week after delivery. (After Dr. Montgomery.)

corpora lutea of virgins being of smaller size than those that are the consequences of impregnation; and Dr. Montgomery[4] says, he has

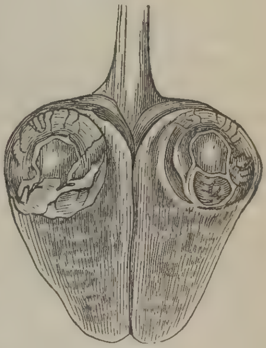
[1] Pouchet, Théorie positive de l'Ovulation spontanée, &c., p. 127, Paris, 1847.
[2] Researches, Physiol. and Pathological, p. 49, Lond., 1825.
[3] Transactions of the Royal College of Physicians of London, vol. vi.
[4] An Exposition of the Signs and Symptoms of Pregnancy, &c., p. 245, Lond., 1837, or

seen many of these virgin corpora lutea, "as they are unhappily called," and has preserved several specimens of them; but not in any instance did they present what he would regard as even an approach to the assemblage of characters belonging to a true corpus luteum,—the result of impregnation; from which, according to him, they differ in the following particulars:—1. There is no prominence or enlargement of the ovary over them. 2. The external cicatrix is almost always wanting. 3. There are often several of them found in both ovaries, especially in subjects who have died of tubercular diseases, such as phthisis, in which case they appear to be merely depositions of tubercle, and are frequently without any discoverable connexion with the Graafian vesicles. 4. They present no trace whatever of vessels in their substance, of which they are, in fact, entirely destitute, and of course cannot be injected. 5. Their texture is sometimes so infirm, that it seems to be merely the remains of a coagulum, and at others appears fibro-cellular like that of the internal structure of the ovary; but never presents the soft, rich, lobulated, and regularly glandular appearance, which Hunter meant to express, when he described them as "tender and friable like glandular flesh." 6. In form they are often triangular, or square, or of some figure bounded by straight lines; and 7. They never present either the central cavity or the radiated or stelliform white line, which results from its closure. Figures 391 and 392, from Dr. Montgomery, represent the corpus luteum in the third, and at the end of the ninth month respectively.

Fig. 391.

Corpus Luteum in the Third Month. (Montgomery.)

Fig. 392.



Corpus Luteum at the end of the Ninth Month. (Montgomery.)

Dr. William Davidson,[1] of Edinburgh, however, has published three dissections of females—not one of whom was pregnant—and in each, corpora lutea were found. They all possessed the characters assigned them by Dr. Montgomery, a central cavity, or fibrous coagulum; an oval form, and a radiated white cicatrix in the centre, just about the central body, which was *immediately* under the peritoneal coat. This last point is dwelt upon by Dr. Robert Lee, who maintains, that false corpora lutea are never observed in immediate connexion with the peritoneum,—a small portion of stroma intervening. One of the females had been in a weakly condition for some years, and had no children; another was unmarried, and had menstruated three days previous to her death; of the third, there was no history, but all the organs were

Amer. Med. Lib. edit., Philad., 1839; or art. Signs of Pregnancy and Delivery, in Cyclop. of Pract. Medicine, Amer. edit. by the author, Philad., 1844.

[1] Lond. and Edinb. Monthly Journal of Med. Science, Dec. 1841.

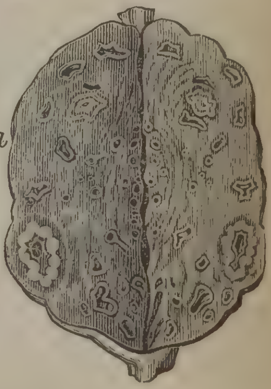
healthy, and the Fallopian tubes and uterus in every respect natural. Dr. Davidson expresses his confident opinion, that in none of the cases had there been impregnation prior to the appearance of these bodies; and he refers to Professors Alison, Allen Thomson, John Reid, and Goodsir, in proof of the accuracy of his statement, and of their perfect resemblance to true corpora lutea. He states, as the result of his investigations, the belief, that impregnation cannot take place without the appearance of a true corpus luteum, but that a true corpus luteum may appear independently of impregnation. That the latter is the case in animals has been shown by the recent researches of Bischoff[1] and others.

It is not yet decided at what period the central cavity disappears or closes up to form the stellated line. Dr. Montgomery thinks he has invariably found it existing up to the end of the fourth month. He has one specimen in which it was closed in the fifth, and another in which it was open in the sixth; but later than this he has never found it.

The structure of the corpus luteum is of a peculiar kind, and is not distinctly seen in small animals, or in those that have numerous litters; but in the cow, which commonly has only one calf at a birth, it is so large, according to Sir Everard Home,[2] that, when magnified, the structure can be made out. It is a mass of thin convolutions, bearing a greater resemblance to those of the brain than to any other organ. Its shape is irregularly oval, with a central cavity, and in some animals, its substance is of a bright orange colour, when first exposed. The corpora lutea are found to make their appearance immediately after puberty, and they continue to succeed each other, as the ova are

Fig. 393.

Fig. 394.



Corpora Lutea. (Sir E. Home.)

expelled, till the period arrives when impregnation can no longer be accomplished. Sir Everard's theory, regarding these bodies, is, that

[1] Beweis der von Begattung unabhängigen periodischen Reifung und Loslösung der Eier. Giessen, 1844; translated in Lond. Med. Gaz., Jan. 13, 17, &c., 1845.

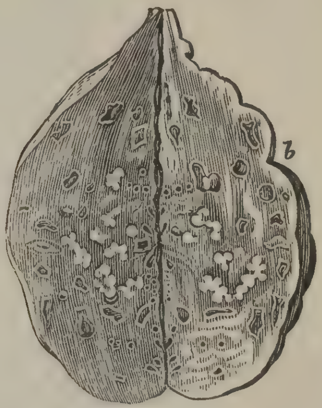
[2] Lect. on Comp. Anat., iii. 303.

they are glands, formed purposely for the production of ova,—and a similar view is entertained by Seiler;[1] that they exist previous to, and are unconnected with sexual intercourse; and, when they have fulfilled their office of forming ova, they are removed by absorption, whether the ova be fecundated or not.

Figures 393 and 394 afford an external and internal view of a human ovary, that did not contain the ovum, from which a child had been developed. It was taken immediately after the child was born. The corpus luteum is nearly of the full size. Figs. 395 and 396 afford an

Fig. 395.

Fig. 396.



Corpora Lutea. (Sir E. Home.)

external and internal view of the ovary, from which the impregnated ovum had escaped. Figure *b* exhibits how much the corpus luteum had been broken down. In it is seen a new corpus luteum forming.

From all these facts, it was at one time concluded by Sir Everard Home,[2] Messrs. Blundell, Saumarez,[3] Cuvier, and others,[4] that something resembling a corpus luteum may be produced independently of sexual intercourse, by the mere excitement of high carnal desire, and perhaps without it, during which the digitated extremity of the Fallopian tube embraced the ovary, a vesicle burst its covering, and a yellow body remained. The ovule conveyed along the tube into the uterus being infecund, underwent no farther developement; so that unimpregnated ova may,—it was inferred,—under such circumstances, be discharged as we observe in the oviparous animal. That infecund ova are thus discharged by the mammalia is now universally admitted. It has been generally denied, however, of late, that the intervention of the male has any influence whatever over it; but the observations of

[1] Das Ei und die Gebärmutter des Menschen, u. s. w., Dresd., 1832.

[2] Op. cit., iii. 304.

[3] A New System of Physiology, i. 337.

[4] For a history of the opinions entertained at various times regarding the corpus luteum, see Dr. Paterson, Edinb. Med. and Surg. Journal, April, 1841, p. 402.

M. Coste[1] demonstrate, that this opinion is too exclusive. He found in rabbits killed from ten to fifteen hours after intercourse, that the ova had generally quitted the ovaries; whilst they were as generally retained where the female was carefully kept from the male.

When pregnancy is over, the corpus luteum gradually diminishes in size and disappears. Dr. Montgomery was unable to fix the exact period of its total disappearance; but he has found it distinctly visible so late as the end of five months after delivery at the full time, but not beyond this period. It would seem, therefore, that a few months after the termination of pregnancy, all traces of the corpus luteum are lost; and that, consequently, it must be impracticable to decide how frequently impregnation has taken place, by examining the ovaries.

Such have been the sentiments of physiologists in regard to the formation of corpora lutea;—a marked difference being admitted by most of them to exist between those that result from the escape of infecund ova, and those that are the consequence of the escape of the impregnated; whilst others have regarded them as identical. With those, however, who maintain that ova always leave the ovary prior to fecundation, it would seem to be consistent to presume, that the corpora lutea are alike in all cases; and hence, that the ovaries can furnish no probable solution after death, by the appearance presented by the corpora lutea, of the question, whether the female had been impregnated or not. M. Raciborski, at one time maintained this doctrine, affirming, that not merely as a result of conception, but at each menstrual period, the discharge of an ovum is followed by the formation of a corpus luteum. Since then, however, he appears to have changed his sentiments as regards the human female, but maintains that such is the fact in animals,—after each period of heat a corpus luteum being formed, which is undistinguishable from that formed after fecundation. The conclusions to which he now arrives are the following. *First.* Corpora lutea are produced by hypertrophy of the granular substance which lines the internal membrane of the Graafian vesicle. *Secondly.* The transformation of this substance commences as soon as the ovule attains maturity, and the vesicle is then prepared to break and give passage to it. *Thirdly.* As soon as the Graafian follicles burst, the transformation is rapidly developed. But an important distinction occurs. If the ovum has been expelled spontaneously—as at every menstrual period—the granulations increase in number and size, under the form of a thin, yellowish membrane, adherent to the membrane of the vesicle; and, in the cavity which it forms, a small clot of blood is to be found. If, on the contrary, conception coincides with the expulsion, the elements of the granular tunic increase so much in size and number, that in a little time they form a voluminous mass, which fills the whole cavity of the vesicle. In the centre of this yellow mass, a small whitish fibrinous tissue—the cicatrix indicating a former cavity—is with difficulty distinguishable. *Fourthly.* In all females delivered at the full period, corpora lutea of this description exist; but they

[1] Histoire générale et particulière du Développement des corps organisés, p. 183, Paris, 1847.

rapidly waste and disappear after delivery. *Fifthly.* It results from the above, that by simple inspection, cases of simple spontaneous expulsion of ova may be readily distinguished from those that have been followed by impregnation.[1]

They, who consider that fecundation is not accomplished in the ovary, must believe, that the ovarian changes, which accompany and signalize fecundation are produced by some reflex action from the uterus; and such is the view embraced by Dr. Ritchie, who has made elaborate inquiries on this whole subject. A similar view is maintained by M. Coste.[2] "When the fecundated ovum"—he remarks—"has attached itself in the uterus, it impresses on that organ an increase of activity, which lasts through the whole term of utero-gestation; extends its influence to the ruptured ovarian capsule, and gives a greater intensity to the process of cicatrization."

It has been a matter of discussion with histologists, whether the substance of the corpus luteum be deposited within the Graafian vesicle, externally to it, or between its layers, or whether it does not consist of a hypertrophied condition of the inner layer or ovisac. Von Baer, Valentin, Wagner, Bischoff, Raciborski, Zwicky, and others embrace the first and most probable opinion; and from an examination of many human corpora lutea in various stages of their growth, Dr. Baly[3] is satisfied, that this is the correct opinion; whilst MM. Pouchet and Coste embrace the last view; Dr. Robert Lee, Mr. T. Wharton Jones, the second; and Drs. Montgomery, Barry, Paterson, Ritchie, F. Renaud, and others, the third.

Dr. Ritchie[4] has shown, that a great variety of changes may take place in the ovary after the ovum has been discharged, amongst which may be included all the appearances depicted by those observers. Besides varying in seat, they differ considerably, he states, in aspect and character;—some being of a white colour, *corpora albida;* others brain-like,—*corpora cephaloidea;* and others, at first, similar to the last, but becoming subsequently of a decidedly red colour—*corpora rubra.* The *corpora albida* may exist under two forms;—first as *soft* bodies of a yellowish fatty appearance, having the outer coat much thickened, whilst the inner remains as a delicate diaphanous pellicle: these, after a long period, present themselves as yellowish-white, and generally globular bodies, more or less fissured from their contraction, and sometimes in process of absorption; having a granular-looking structure, and seldom divisible into laminæ by dissection; and secondly, as *dense* bodies of a whitish, shining, firm structure, the inner coat being the seat of those changes, and the outer adhering loosely as a transparent pellicular layer. The inner layer has the appearance of a thick, opaque, deeply wrinkled cyst; or is sometimes partially diaphanous, and of a shining pearly aspect, and white colour; and sometimes

[1] Bulletin de l'Académie Royale de Médecine, Oct. and Nov. 1844; cited in Med. Examiner, June, 1845, p. 384.

[2] Op. cit., p. 259.

[3] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation and Developement, p. 54, Lond., 1848.

[4] Op. cit.; also, Carpenter, Principles of Human Physiology, 2d Amer. edit., p. 597.

contains a yellow, greenish, transparent fluid, or a clot of blood, either unchanged, or converted into a yellow or black pigment. Of the *corpora cephaloidea* Dr. Ritchie depicts many varieties, according as the cerebriform matter is deposited between the layers of ruptured follicles, having transparent pellicular walls, or having their inner or outer coat thickened; or externally to the two inner layers of the follicle. The last variety only was met with exclusively in the fecundated female. They were generally distinguished by large, persistent, white, glistening cavities. The granular cephaloid matter was sometimes found quite absorbed, a few days after delivery; but, in other instances, it underwent changes characteristic of the next class.

The *corpora rubra* are peculiar to the impregnated and suckling female—in the period between the eighth and thirteenth months after conception. They appeared to Dr. Ritchie to be a conversion of the corpora cephaloidea, arising out of a higher and more perfect organization. Down to the seventh month of utero-gestation, the cysts contained in the ovaries do not differ from the cephaloid bodies found in the unimpregnated state, except that they are sometimes plumper; more vascular; better developed, and had their inner layer more frequently thickened. A change of the granular hue, then commences, which becomes more and more decided; so that by the end of the first month after delivery, it is of a decided rose colour, changing to a still more florid hue on exposure to air. Its cavity also contracts, so as to leave only a stellated point, or a curved groove, with a fibrous appearance in the surrounding substance.

Although corpora rubra are found exclusively in the latter months of pregnancy, or in the puerperal state, yet, they are not always present in those conditions. The form of corpora cephaloidea described above, and the corpora rubra, according to Dr. Ritchie, alone coincide with pregnancy.

The cause of the yellow colour of the corpora lutea has been a ground of dispute; but it is obviously of no more moment than that of the other varieties of colour presented by those bodies. By MM. Pouchet,[1] Raciborski,[2] and others, it has been ascribed to extravasation and imbibition by the hypertrophied lining membrane, similar to that which occurs in ecchymoses, or in the neurine in cases of encephalic hemorrhage; but others[3] do not accord with this view. From the appearances presented under the microscope, Dr. Meigs argues, that the yolk of eggs and the yellow matter from a corpus luteum "are of the same apparent constitution, form, colour, odour, coagulability, refractive power, and microscopic appearance;" and M. Coste appears to be of the same opinion. Dr. Meigs,[4] for these reasons, considers it a true "*vitellary matter.*" The propriety of such a name may be questioned, however, upon the same ground, that we might hesitate in calling a substance

[1] Théorie positive de l'Ovulation spontanée, p. 146, Paris, 1847.
[2] De la Puberté et de l'Age critique chez la Femme, p. 437, Paris, 1844.
[3] Coste, Op. cit., and Kirkes and Paget, Manual of Physiology, Amer. edit., p. 467, Philad., 1849.
[4] Transactions of the American Philosophical Society for 1847, p. 131; and Obstetrics: the Science and the Art, by Charles D. Meigs, M.D., p. 107, Philad., 1849.

which contains cholesterin, *biliary matter;* as cholesterin is a constituent of many morbid formations totally unconnected with the liver, or its secretion. That the colouring matter of the vitellus or yolk and that of the corpus luteum are analogous—if not identical—is probable, under the view which we embrace,—that the corpus luteum is constituted essentially of the enlarged cells and granules of yellow fatty matter that line the Graafian vesicle and form the membrana granulosa. The enlargement of the cells, according to Zwicky,[1] who minutely examined the corpora lutea in cows and sows, appears to depend on an accumulation of the fat granules which the Graafian vesicles always contain; and the yellow colour, when it exists, is contained in those fat granules and other fatty particles. When it is borne in mind, that the vitellary matter of the ovum must be secreted from the same lining membrane of the Graafian vesicle as the membrana granulosa, there need be no difficulty in comprehending, that the yolk and the corpus luteum may be of identical or analogous composition, and conduct themselves alike under the microscope, and the employment of reagents. In function, however, they are in no respect identical or analogous.

It is obvious, that the whole subject of the value of the corpora lutea as an index of fecundation is in an unsettled condition; and, consequently, the medical jurist must be exceedingly cautious, from their appearance, in giving decided testimony in a court of justice; for although, as has been seen, some observers—Dr. Montgomery, for example—have pronounced strongly in regard to the markedly distinctive characters of the corpora lutea of impregnation; and M. Coste[2] expresses his belief in the possibility of distinguishing by them whether a female was or was not pregnant, and is persuaded, that important applications will ultimately be made of this knowledge in legal medicine; others—as Dr. Davidson—have deposed as strongly to the absence of such characteristics; and all must admit, that in the present state of knowledge, the mere fact of the existence of a corpus luteum ought not to be taken as a positive evidence of previous impregnation. The difficulty of accurate decision is, indeed, sufficiently shown by a controversy between two distinguished observers and writers on this matter,—Dr. R. Paterson, and Dr. Robert Lee. Dr. Paterson[3] had described what he conceived to be an early corpus luteum. This was designated by Dr. Lee, in his lectures, as a mere clot of blood; and he afterwards affirmed, that "the said clot of blood did not present one of the characters of a true corpus luteum;" and that if he "was summoned into a court of justice, he would have no hesitation in declaring upon oath, from the evidence furnished, that the proofs of pregnancy were wholly wanting." Dissatisfied with these remarks, Dr. Paterson forwarded, through a friend, the specimen in question, without stating what it was, to obtain Dr. Lee's unbiassed opinion of it from personal inspection; when, after a careful examination, Dr. Lee returned an answer, declaring it to be an early true corpus luteum, and requested permission to

[1] De Corporum Luteorum Origine atque Transformatione, cited by Mr. Paget in his Report on the Progress of Human Anatomy and Physiology, in the years 1844–5, in British and Foreign Medical Review, July, 1846, p. 290; also, Baly and Kirkes, op. cit., p. 53.

[2] Op. cit., p. 260.

[3] Edinb. Med. and Surg. Journ., No. 142.

describe it as such before the Royal Medico-Chirurgical Society of London ![1]

In regard to the offices performed by corpora lutea, difference of sentiment has existed, and still exists: Sir Everard Home—as has been seen—adopts the opinion of Vallisnieri, that they are glandular formations concerned in the production of ova. Others have supposed, that they furnish the ovum with the first materials that are needed for its developement.[2] The generality of physiologists, perhaps, regard them as the result of a simple process of cicatrization set up in the emptied vesicle—a process, which, according to Bischoff,[3] bears the greatest analogy to that of the closure and healing of an abscess.

c. *Theories of Generation.*

We have now endeavoured to demonstrate the part performed by the two sexes in fecundation. It has been seen, that the material furnished by the male is sperm; that afforded by the female an ovum. The most difficult topic of inquiry yet remains,—how the new individual results from their commixture? Of the nature of this mysterious process we are profoundly ignorant; and if we could make any comparison between the extent of our ignorance of the different vital phenomena, we should be disposed to decide, that the function of generation is one of the least intelligible. The new being must be stamped instantaneously as by a die. From the very moment of the admixture of the materials at a fecundating copulation, the embryo must have within it the powers necessary for its own formation,—impulses communicated by each parent, as regards likeness, hereditary predisposition, &c. From that moment the father has no communication with it; yet we know, that it may resemble him in its features and predispositions to certain morbid states,—whilst the mother probably exerts but a slight and indirect control over it afterwards; her office being chiefly to furnish the homunculus with a nidus, in which it may work its own formation, and with the necessary pabulum. We have seen, that even so early as the seventh and eighth day after fecundation, two projecting points—it has been asserted—have been observed in the ovum, which indicate the future situations of the brain and spinal marrow. [?] Our want of acquaintance with the precise character of this impenetrable mystery will not, however, excuse us from passing over some of the ingenious hypotheses, that have been entertained. These have varied according to the views that prevailed respecting the nature of the sperm; and to the opinions indulged regarding the matter furnished by the ovary. Drelincourt,[4] who died in 1697, collected as many as two hundred and sixty hypotheses of generation; but they may all, perhaps, be classed under two,—the system of *epigenesis* and that of *evolution*.

1. *Epigenesis.*—According to this system, which is the most ancient of all, the new being is conceived to be built up of materials furnished

[1] R. Paterson, in Edinb. Med. and Surg. Journ., Oct., 1844, p. 467.

[2] Montgomery, On the Signs and Symptoms of Pregnancy, &c., Amer. Med. Libr. edit., p. 149, Philad., 1839.

[3] Développement de l'Homme, &c., traduit par Jourdan, p. 44, Paris, 1843.

[4] Novem Libelli de Utero, Conceptione, Fœtu, &c., Lugd. Bat., 1632.

by both sexes, the particles composing those materials having previously possessed the arrangement necessary for constituting it,—or having suddenly received such arrangement. Still, it is requisite that these particles should have some controlling force to regulate their affinity, different from the ordinary forces of matter; and hence one has been imagined to exist, which has been termed *cosmic*, *plastic*, *essential*, *nisus formativus*—Bildungstrieb of the Germans—*force of formations*, &c.

Hippocrates[1] maintains, that each of the two sexes possesses two kinds of seed, formed by the superfluous nutriment, and by fluids constituted of materials proceeding from all parts of the body, and especially from the most essential,—the nervous. Of these two seeds, the stronger begets males, the weaker females. In the act of generation, these seeds are commingled in the uterus; and through the influence of the heat of that organ, they form the new individual—by a kind of animal crystallization—male or female, according to the predominance of the stronger or the weaker seed. Aristotle[2] thought, that it is not by seed that the female participates in generation, but by menstrual blood. This he conceived is the basis of the new individual, whilst the principles furnished by the male communicate to it the vital movement, and fashion it. Empedocles, Epicurus, and various other ancient physiologists, contended, that the male and female respectively contribute a seminal fluid, which co-operate equally in the generation and developement of the fœtus; and that it belongs to the male or female sex, or resembles more closely the father or the mother, according as the orgasm of the one or the other predominates, or is accompanied by a more copious emission.

> "Semper enim partus duplici de semine constat;
> Atque utrique simile est magis id quodcumque creatur."
>
> LUCRET., lib. iv.

Lactantius, on quoting the views of Aristotle, fancifully affirms, that the right side of the uterus is the proper chamber for the male fœtus; the left for the female,—a belief, which appears to be still prevalent amongst the vulgar in many parts of Great Britain. But he adds; if the male or stronger semen should, by mischance, enter the left side of the uterus, a male child may still be conceived; yet, as it occupies the female department, its voice, face, &c., will be effeminate. On the contrary, if the weaker or female seed should flow into the right side of the uterus, and a female fœtus be engendered, it will exhibit evidences of a masculine character.

The idea of Aristotle with regard to the menstrual blood has met with few partisans, and is undeserving of farther notice. That of Hippocrates, notwithstanding the objections,—that the female furnishes no sperm, and the ovaria are in no respect analogous to the testes,—has had numerous supporters amongst the moderns, modified, however, to suit the scientific ideas of the time, and the individual. Des Cartes, for example, considered the new being to arise from a kind of fermenta-

[1] Περὶ γονῆς; in Oper. Omnia, edit. A. Foësio. Genev., 1657–1662.
[2] De Generatione Animalium, &c., i. 19.

tion of the seed furnished by both sexes. Pascal, that the sperm of the male is acid; that of the female alkaline; and that they combine to form the embryo. Maupertuis[1] maintained, that, in each seed parts exist adapted for the formation of every organ of the body, and that, at the time of the union of the seed in a fecundating copulation, each of the parts is properly attracted and aggregated by a kind of crystallization.[2]

The celebrated hypothesis of the eloquent and enthusiastic Buffon[3] is but a modification of the Hippocratic doctrine of epigenesis. According to him, there exist in nature two kinds of matter,—living and dead; the former perpetually changing during life, and consisting of an infinite number of small, incorruptible particles or primordial monads, which he called *organic molecules.* These molecules, by combining in greater or less quantity with dead matter, form all organized bodies: and without undergoing destruction are incessantly passing from vegetables to animals in the nutrition of the latter, and are returned from the animal to the vegetable by the death and putrefaction of the former. These organic molecules, during the period of growth, are appropriated to the developement of the individual; but as soon as he has acquired his full size the superfluous molecules are sent into depot in the genital organs, each molecule being invested with the shape of the part sending it. In this way, he conceived, the seed of both sexes is formed of molecules obtained from every part of the system. In the commixture of the seeds during a fecundating copulation, the same force that assimilates the organic molecules to the parts of the body for their nourishment and increase causes them to congregate for the formation of the new individual; and according as the molecules of the male or female predominate, so is the embryo male or female.

The ingenuity of this doctrine was captivating; and it appeared so well adapted for the explanation of many of the phenomena of generation, that it had numerous and respectable votaries. It accounted for the circumstance of procreation not being practicable until the system has undergone its developement at puberty. It explained why excessive indulgence in venery occasions emaciation and exhaustion; and why, on the other hand, the castrated animal is disposed to obesity,—the depot having been removed by the mutilation. The resemblance of the child to one parent rather than to the other was supposed to be owing to the one furnishing a greater proportion of organic molecules than the other; and as more males than females are born, the circumstance was ascribed to the male being usually stronger, and therefore furnishing a stronger seed, or more of it.

Prior to this hypothesis, Leeuenhoek[4] had discovered what he considered to be spermatic animalcules in the semen; but Buffon contested their animalcular nature, and regarded them as his vital particles or organic molecules; whilst he looked upon the ovarian vesicle as the capsule that contains the sperm of the female. The opinions of Buffon

[1] Venus Physique, Paris, 1751.
[2] Adelon, Physiologie de l'Homme, iv. 85, 2de édit., Paris, 1829.
[3] Histoire Naturelle, tom. xvii., &c., Paris, 1799.
[4] Arcania Naturæ, Lugd. Bat., 1685.

were slightly modified by Blumenbach[1] and Darwin.[2] The former, like Buffon, divided matter into two kinds, possessing properties essentially different from each other;—the inorganic and the organized; the latter possessing a peculiar creative or formative impulse, which he termed Bildungstrieb or *nisus formativus*,—a principle in many respects resembling gravitation, and endowing every organized tissue with a *vita propria*. This force, he conceived, presides over the arrangement of materials furnished by the sexes in generation. Darwin preferred to the term "organic molecules" that of *vital germs*, which, he maintains, are of two kinds, according as they are secreted or provided by male or female organs, whether animal or vegetable. In the subdivision, however, of the germs he retained the term *molecule;* but limited it to those of the female;—the vital germs or particles, secreted by the female organs of a bud or flower, or the female particles of an animal, being denominated by him *molecules* with formative propensities; whilst those secreted from the male organs he termed *fibrils* with formative appetencies. To the fibrils he assigned a higher degree of organization than to the molecules. Both, however, have a propensity or appetency to form or create, and "they reciprocally stimulate and embrace each other and instantly coalesce; and may thus be popularly compared to the double affinities of chemistry."

Subtile as are these hypotheses, they are open to forcible objections, of which a few only will suffice. The notion of this occult force is identical with that, which has prevailed in regard to life in general, and leaves the subject in the same obscurity. What do the terms *plastic*, *cosmic*, or *vegetative force*, or Bildungstrieb express, which is not equally conveyed by *vital force*,—that mysterious power, on which so many unfathomable processes of the animal body are dependent, and of the nature or essence of which we know absolutely nothing? The objection, urged against the doctrine of Hippocrates,—that we have no evidence of the existence of female sperm,—applies equally to the hypotheses that have been founded upon it; and even were we to grant, that the ovarium is a receptacle for female sperm, the idea, that such sperm is constituted of organic molecules derived from every part of the body would still be gratuitous. We have no facts to demonstrate the affirmative; whilst there are many circumstances, that favour the negative. A person, for example, who has lost some part of his person—nose, eye, or ear, or has had a limb amputated, or been circumcised—still begets perfect children. Whence can the molecules, in such cases, have been obtained? It is true, that if the mutilation affect but one parent, the organic molecules of the lost part may still exist in the seed of the other; but we ought, at least, to expect the part to be less perfectly formed; which is not the case. Where two docked horses are made to engender, the result ought, *à fortiori*, to be imperfect, as the organic molecules of the tail could not be furnished by either parent, yet we find the colt in such cases, perfect in this appendage. An elucidative case is afforded by the fœtus. If we admit the possibility of organic

[1] Ueber den Bildungstrieb, Gotting, 1791; Comment. Societat. Gotting., tom. viii.; and Institutiones Physiologicæ, sect. xl. p. 459, Gotting., 1798.

[2] Zoonomia, sect. xxxix., 8, 10, 3d edit., vol. ii., London, 1801.

molecules constituting those parts that exist in the parents, how can we account for the formation of such as are peculiar to fœtal existence? Whence are the organic molecules of the umbilical cord, or umbilical vein, or ductus venosus, or ductus arteriosus, or umbilical arteries obtained? These and other objections have led to the abandonment of the theory of Buffon, which remains a monument of the author's ingenuity and elevation of fancy,—not of his solidity.

2. *Evolution.*—According to this theory, the new being preexists in some shape in one sex, but requires to be vivified by the other in the act of generation; after which it commences a series of developements or *evolutions*, which lead to the formation of an independent being. The great differences of sentiment that have prevailed under this view, have been as regards the part, which each sex has been conceived to play in the function. Some have considered the germ to exist in the ovary, and to require the vivifying influence of the male sperm to cause its evolution. Others have conceived the male sperm to contain the rudiments of the new being, and the female to afford it merely a nidus, and pabulum during its developement. The former class of physiologists have been called *ovarists* or *ovists;*—the latter *spermatists*, *seminists*, and *animalculists.* The ovarists maintain, that the part furnished by the female is an ovarian ovum, which, they conceive, is formed of an embryo and particular organs for its nutrition and first developement;—the embryo adapted for becoming, after a series of changes or evolutions, a being similar to the one whence it has emanated. This hypothesis was suggested by the fact, that in many animals a single individual only is necessary for reproduction, and it being easier, perhaps, to conceive this individual to be female than male; as well as by what is noticed in many oviparous animals. In them, the part, furnished by the female, is manifestly an ovum or egg; and in many, such egg is laid before the union of the sexes; and fecundated externally. By analogy, the inference was drawn, that this may happen to the viviparous animal likewise. The notion is said, but erroneously, to have been first advanced by Joseph de Aromatariis.[1] It was developed by Harvey,[2] who strenuously maintained the doctrine—*omne vivum ex ovo.* The anatomical examinations of Sylvius, Vesalius, Fallopius, De Graaf,[3] Malpighi,[4] Vallisnieri[5] and others,—by showing, that what had been previously regarded as female testes, and had been so called, were organs containing minute vesicles or ova, and hence termed by Steno *ovaria*,—were strong confirmations of this view, and startling objections to the ancient theory of epigenesis; and the problem appeared to be demonstrated, when it was discovered, that the vesicle or ovum leaves the ovary and passes through the Fallopian tube to the uterus.

The chief arguments that have been adduced in favour of the doctrine are:—*First.* The difficulty of conceiving the formation, *ab origine*, of an organized body, as no one part can exist without the simultaneous exist-

[1] Epist. de Generatione Plantarum ex Seminibus, Venet., 1625.
[2] Exercitationes de Generatione Animalium, Lond., 1651.
[3] De Organis Mulierum, &c., Lugd. Bat., 1672.
[4] Append. ad Opera Omnia, Lugd. Bat., 1687.
[5] Istoria della Generazione dell'Uomo, Discorsi Acad. i.–iv., Venez., 1722–1726.

ence of others. *Secondly.* The presence of the germ in many living beings prior to fecundation. In plants, for example, the grain exists in a rudimental state in the flower, before the pollen, which has to fecundate it, has attained maturity. In birds, too, the egg must pre-exist, as we find that those, which have never had intercourse with the male, can lay. This is more strikingly manifest in many fishes, and in the *batracia* or frog kind, where the egg is not fecundated until after it has been extruded. Spallanzani, moreover, asserts, that he could distinguish the presence of the tadpole in the unfecundated ova of the frog; and Haller, that of the chick in the infecund egg: he has seen them containing the yolk, which, in his view, is but a dependence of the intestine of the fœtus, and if the yolk exist, the chick, he argues, must exist also. [!] *Thirdly.* The fact, before referred to, that in certain animals, a single copulation is capable of fecundating several successive generations. In these cases, it is argued, the germ of the different generations must have existed in the first. *Fourthly.* The fact of natural and accidental encasings, inclusions or *emboîtements*,—as in the bulb of the hyacinth, in which the rudiments of the flower are distinguishable; in the buds of trees, in which the branches, leaves, and flowers, have been detected in miniature, and greatly convoluted; in the jaws of certain animals, in which the germs of different series of teeth can be detected; in the volvox, a transparent animal, which exhibits several young encased in each other; in the common egg, which occasionally has another within it; and in the instances on record, in which a human fœtus has been found encased—*fœtus in fœtu*—many cases of which are referred to by Professor Vrolik;[1] and of which there is a striking example in a youth in the Museum of the Royal College of Surgeons, of London; and a similar one, in a boy fourteen years of age, has been recorded by Dupuytren. A most singular case of the kind occurred to M. Velpeau.[2] A tumour was removed from the scrotum of a young man aged 27, which was found to contain almost all the elements of a human body. Its exterior was evidently tegumentary, and the greater part of its substance a mixture of lamellæ and fibres like areolar, adipous, muscular, and fibrous tissues. In the interior, there were two cysts filled with a substance like albumen or the vitreous humour; another cyst, as large as a partridge's egg, containing a greenish semi-fluid matter like meconium; and a fourth contained a dirty yellow grumous mass surrounded by hairs: the mass consisted of sebaceous matter and scales of epidermis: the hairs had no bulbs. A tuft of hair, which protruded externally from a kind of ulcer at the posterior part,—and which, with the fact of the tumour being congenital, induced M. Velpeau to consider it to be fœtal,—proceeded from the cyst that contained the meconium-like substance, and gave the opening into it somewhat the appearance of an anus. In the midst of all these, numerous perfectly organized portions of a skeleton were found, consisting of bones resembling more or less the clavicle, scapula, humerus, sphenoid bone, sacrum, portions of vertebræ, and others whose names could not be determined. A peculiarity

[1] Art. Teratology, in Cyclopædia of Anat. and Physiology, Pt. xxxviii. p. 967, Feb. 1850.
[2] Gazette Médicale, 15 Fév., 1840.

of this case of monstrosity by inclusion was, that the second fœtus did not act as a foreign body in the other, but had a separate and independent existence and power of growth within itself. The tumour had its own colour and consistence, and a sensibility entirely independent of the person to whom it was attached. The man himself pierced it several times with a knife without feeling the least pain; and yet, all the wounds that were made in it bled, inflamed and cicatrized like those of any other part of the body.

Perhaps, the explanation of these extraordinary cases by Dr. Blundell[1] is as philosophical as any that could be devised. A seed or egg, though fecundated, may lie for years without being evolved. A serpent may become enclosed under the eggshell of the goose; the shell probably forming over it as the animal lies in the oviduct of the bird. These facts Dr. Blundell applies to the phenomenon in question. When the boy was begotten, a twin was begotten at the same time,—but, while the former underwent his developement in the usual manner, the impregnated ovum of his companion lay dormant, and unresistingly became closed up within the fraternal structure, as the viper in the eggshell. For a few years, these living rudiments generally lie quiet within the body, and ultimately become developed so as to occasion the death of both. "The boy," he remarks—speaking of one of the cases—"became pregnant with his twin brother; his abdomen formed the receptacle, where, as in the nest of a bird, the formation was accomplished." Cases of this kind of arrest of developement occasionally occur, where two or more ova are fecundated at the same time, or in succession. To this we shall refer under Superfœtation. *Fifthly.* The fact of the various metamorphoses that take place in certain animals. Of these we have the most familiar instances in the batracia, and in insects. The forms which they have successively to assume are evidently encased within each other. In the chrysalis, the outlines of the form of the future butterfly are apparent; and in the larva we observe those of the chrysalis. The frog is apparent under the skin of the tadpole. *Sixthly.* The fact of artificial fecundation, which has been regarded by the ovarists as one of the strongest proofs of their theory;—the quantity of sperm employed, as in the experiments of Spallanzani already detailed, being too small, in their opinion, to assist in the formation of the new individual, except as a vivifying material. *Lastly.* They invoke the circumstance of partial reproduction, of which all living bodies afford more or less manifest examples;—as that of the hair and nails of man; the teeth of the rodentia; the tail of the lizard; the claw of the lobster; the head of the snail, &c., &c. All these phenomena, according to them, are owing to each part possessing within itself germs destined for its reproduction; and requiring only favourable circumstances for their developement. The partisans of the doctrine of epigenesis, however, consider these last facts as opposed to the views of the ovarists; and maintain, that, in such cases, there is throughout a fresh formation.

[1] Principles and Practice of Obstetricy, edited by Dr. Castle, London, 1834; American edition, Washington.

The chief objections, that have been urged against the hypothesis of the ovarists, are:—*First.* The resemblance of the child to the father —a subject to be referred to presently. The ovarists cannot of course deny that such resemblance exists; and they ascribe it to the modifying influence exerted by the male sperm; but without being able to explain the nature of such influence. They affirm, however, that the likeness to the mother is more frequent and evident. But certain cases of resemblance are weighty stumbling-blocks to ovism or the doctrine of a pre-existing germ in the female. It is a well-known fact, that six-fingered men occasionally beget six-fingered children. How can we explain this upon the principle of the pre-existence of the germ in the female, and of the part played by the male sperm being simply that of vivifying? and must we suppose, in the case of monstrosities, that such germs were originally monstrous? *Secondly.* The production of *hybrids* is one of the strongest counter-arguments. They are produced by the union of the male and female of different species. Of these, the mule is the most familiar instance,—the product of the ass and the mare. It strikingly participates in the qualities of both parents; and, consequently, the pre-existing germ in the female must have been more than vivified by the sexual intercourse. Its structure must have been altogether changed, and all the germs of its future offspring annihilated, for the mule is seldom fertile. If a white woman marries a negro, the child is a mulatto; and if the successive generations of this be united to negroes, the progeny will ultimately become entirely black; or, at least, the white admixture will be so small as to escape recognition. As a general rule, the offspring of different races has an intermediate tint between that of the parents. The proportions of white and black blood, in different admixtures, have even been subjected to calculation, in countries where negroes are common. The following table represents these proportions, according to principles sanctioned by custom.

Parents.	Offspring.	Degrees of Mixture.	
Negro and white,	mulatto,	$\frac{1}{2}$ white,	$\frac{1}{2}$ black.
White and mulatto,	terceron,	$\frac{3}{4}$ —	$\frac{1}{4}$ —
Negro and mulatto,	griffo, griff, or zambo, or black terceron,	$\frac{1}{4}$ —	$\frac{3}{4}$ —
White and terceron,	quarteron, quadroon,	$\frac{7}{8}$ —	$\frac{1}{8}$ —
Negro and terceron,	black quarteron or quadroon,	$\frac{1}{8}$ —	$\frac{7}{8}$ —
White and quarteron,	quinteron,	$\frac{15}{16}$ —	$\frac{1}{16}$ —
Negro and quarteron,	black quinteron,	$\frac{1}{16}$ —	$\frac{15}{16}$ —

The last two, in the British West India Islands,[1] are considered to be respectively white and black; and the former were white by law, and consequently free, when slavery existed there. The following table is given by Tschudi[2] to exhibit the parentage of the different varieties of half casts, and their proper designations:—

[1] Lawrence, Lectures on Physiology, Zoology, and the Natural History of Man, p. 299, Lond., 1819.

[2] Travels in Peru, during the years 1838–1842; translated from the German by Thomasine Ross, Amer. edit., p. 81, New York, 1847.

Parents.	Children.
White father and negro mother,	mulatto.
White father and Indian mother,	mestizo.
Indian father and negro mother,	Chino.
White father and mulatto mother,	cuarteron.
White father and mestiza mother,	creole (only distinguished from the white by a pale brownish complexion).
White father and China mother,	Chino-blanco.
White father and cuarterona mother,	quintero.
White father and quintera mother,	white.
Negro father and mulatto mother,	zambo-negro.
Negro father and mestiza mother,	mulatto oscuro.
Negro father and China mother,	zambo-Chino.
Negro father and zamba mother,	zambo-negro (perfectly black).
Negro father and cuarterona or quintera mother,	mulatto (rather dark).
Indian father and mulatto mother,	Chino-oscuro.
Indian father and mestiza mother,	mestizo-claro (frequently very beautiful).
Indian father and China mother,	Chino-cholo.
Indian father and zamba mother,	zambo-claro.
Indian father and China-chola mother,	Indian (with rather short frizzy hair).
Indian father and cuarterona or quintera mother,	mestizo (rather brown).
Mulatto father and zamba mother,	zambo (a miserable race).
Mulatto father and mestiza mother,	Chino (of rather clear complexion).
Mulatto father and China mother,	Chino (rather dark).

All these cases exhibit the influence exerted by the father upon the character of the offspring, and are great difficulties in the way of supposing, that the male sperm is simply a vivifier of the germ pre-existing in the female.

Thirdly. The doctrine of the ovarists does not account for the greater degree of fertility of cultivated plants and domesticated animals. *Fourthly.* The changes, induced by the succession of ages on the animal and vegetable species inhabiting the surface of the globe, have been adduced against this hypothesis. In examining the geological character of the various strata that compose the earth, it has been observed by geologists, that many of these contain embedded the fossil remains of animals and vegetables. Now those rocks on which others rest are the oldest, and the successive strata above these are more and more modern, and it has been found, that the organic fossil remains in the different strata differ more and more from the present inhabitants of the surface of the globe in proportion to the depth we descend; and that the remains of those beings, that have always been the companions of man, are found only in the most recent of the alluvial deposits,—the upper crust of the earth. It was an opinion, at one time universally embraced, that geological evidence was in favour of animals having been created in the order of their relative perfection, so that the lowest animals; as the polyps and echinoderms occupied the most ancient formations; and to these succeeded the mollusks; then the articulated animals, and, lastly, the vertebrate. More recent investigation has, however, satisfied the geologist, that fossils, belonging to each of the four departments, have been found in the fossiliferous deposits of every age. Four ages of nature, according to Professor Agassiz,[1] may be distinguished, which correspond with the great geological divisions.

[1] Agassiz and Gould, Principles of Zoology, p. 190, Boston, 1848.

First. The *Primary* or *Paleozoic age*, comprising the lower Silurian, the upper Silurian, and the Devonian; during which there were no air-breathing animals. Fishes were the masters of creation, and hence—it has been suggested—this may be called the *Reign of Fishes*. *Secondly.* The *secondary age*, comprising the carboniferous formation, the trias, the oölitic, and the cretaceous formations, in which air-breathing animals first appear; and as the reptiles predominate over the other classes, this has been termed the *Reign of Reptiles*. *Thirdly.* The *tertiary age*, comprising the tertiary formations, during which terrestrial mammals of great size abounded. This was the *Reign of Mammals;* and *Fourthly;* the *modern age*, characterized by the appearance of the most perfect of all created beings. This has been called the *Reign of Man.*

In the older rocks the impressions are chiefly of the less perfect plants, and of the lower animals. In the more recent strata, the remains of reptiles, birds, and quadrupeds are apparent; but they differ essentially from existing kinds, and in none of the formations of more ancient date has the fossil human skeleton been met with. The skeleton of the savage Galibi, from Guadaloupe deposited in the British Museum, is embedded in a calcareous earth of modern formation; and the pretended human bones, conveyed by Spallanzani from the Island of Cerigo—the ancient Cythera—are not those of the human species, any more than the bones of the *Homo diluvii testis* of Scheuchzer. Hence it has been concluded, that man is of a date posterior to animals in all countries where fossil bones have been discovered. It has been attempted to explain these singular facts, furnished by modern geological inquiry, by the supposition, that the present races of animals are the descendants of those whose remains are met with in the rocks, and that their difference of character may have arisen from some change in the physical constitution of the atmosphere, or of the surface of the earth, producing a corresponding change in the forms of organized beings. It has been properly remarked, however, by Dr. Fleming,[1] that the effect of circumstances on the appearance of living beings is circumscribed within certain limits, so that no transmutation of species was ever ascertained to have taken place, whilst the fossil species differ as much from the recent kinds as the last do from each other; and he adds, that it remains for the abettors of the opinion to connect the extinct with the living races, by ascertaining the intermediate links or transitions. This will probably never be practicable. The difference, indeed, between the extinct and living races is in several cases so extreme, that many naturalists have preferred believing in the occasional formation of new organized beings. Linnæus was bold enough to affirm, that, in his time, more species of vegetables were in existence than in former periods, and hence, that new vegetable species must necessarily have been ushered into being; and Wildenow embraced the views of Linnæus. De Lamarck,[2] one of the most distinguished naturalists of his day, openly professed the belief, that both animals and vegetables

[1] Philosophy of Zoology, i. 26, Edinb., 1822.
[2] Philosophie Zoologique, edit. cit., tom. i., p. 218, Paris, 1830.

are incessantly changing under the influence of climate, food, domestication, crossing of breeds, &c., and he remarks, that if the species now in existence appear to us fixed in their characters, it is because the modifying circumstances require an enormous time for action, and would, consequently, require numerous generations to establish the fact. The manifest effect of climate, food, &c., on vegetables and animals, he thinks, precludes the possibility of denying those changes on theoretical considerations; and what we call *lost species* are, in his view, the actual species before they experienced modification. It is proper, however, to observe, that the representations on the wall of one of the sepulchres in the valley of Beban el Molook, at Thebes, which are regarded by Champollion as having been executed upwards of two thousand years before the Christian era, enable the features of the Jew and the negro, amongst others, to be recognised as easily as the representations of their descendants of the present day; so that, for the space of at least three thousand eight hundred years, no modification of the kind referred to by De Lamarck seems to have occurred in the human species.

Another explanation has been offered for these geological facts, and for the rotation, which we observe in the vegetable occupants of particular soils in successive years. It has been supposed, that as the seeds of plants and the ova of certain animals are so excessively minute as to penetrate wherever water or air can enter; and as they are capable of retaining the vital principle for an indefinite length of time, of which we have many proofs, and of undergoing evolution whenever circumstances are favourable, the crust of the earth may be regarded as a receptacle of germs, each of which is ready to expand into vegetable or animal forms, on the occurrence of conditions necessary for their developement. This is the hypothesis of *panspermia* or *dissemination of germs*, according to which the germs of the ferns and reeds were first expanded, and afterwards those of the staminiferous or more perfect vegetables; and, in the animal kingdom, first the polyp, and gradually the being more elevated in the scale; the organized bodies of the first period flourishing, so long as the circumstances favourable to their developement continued, and then making way for the evolution of their successors,—the changes effected in the soil by the growth and decay of the former probably favouring the evolution of the latter; which, again, retained possession of the soil so long as circumstances were propitious.[1] The changes that take place in forest vegetation are favourable to this doctrine. If, in Virginia, the forest trees be removed so as to make way for other growth, and the ground be prepared for the first cultivation, the *Phytolacca decandra* or *poke*, which was not previously perceptible on the land, usurps the surface. When Mr. Madison went with General Lafayette to the Indian treaty, they discovered, wherever trees had been blown down by a hurricane in the spring, that white clover had sprung up in abundance, although the spot was many miles distant from any cleared land; and it has often been remarked, that where, during a drought in the spring, the woods

[1] Fleming, op. citat., i. 28.

have taken fire, and the surface of the ground has been torrefied, the water-weed has made its appearance in immense quantities, and occupied the burnt surface. The late Judge Peters, having occasion to cut ditches on his land, in the western part of Pennsylvania, was surprised to find every subterraneous tree met with differing from those occupying the surface at the time; and President Madison informed the author, that, in the space of sixty or seventy years, he had noticed the following spontaneous rotation of vegetables:—1. Mayweed; 2. Blue centaury; 3. Bottle-brush-grass; 4. Broom-straw; 5. White clover; 6. Wild carrot; and the last was then giving way to the blue grass.

The doctrine of panspermia is, however, totally inapplicable to the viviparous animal, in which the ovum is hatched within the body, and which, consequently, continues to live after the birth of its progeny; and the facts furnished by geology seem clearly to show, that the developement of the animal kingdom has been successive, not simultaneous; but under what circumstances the different animals were successively ushered into being, we know not.

Lastly, as regards the ovarists themselves;—they differ in essential points: whilst some are favourable to the doctrine of the *dissemination of germs*, believing, as we have seen, that ova or germs are disseminated over all space, and that they only undergo developement under favourable circumstances,—as when they meet with bodies capable of retaining them, and causing their growth, or which resemble themselves;—others assert, that the germs are enclosed in each other, and are successively aroused from their torpor, and called into life, by the influence of the seminal fluid; so that not only did the ovary of the first female contain the ova of all the children she had, but one only of these ova contained the whole of the human race. This was the celebrated system of *emboîtement des germes* or *encasing of germs*, already referred to, of which Bonnet[1] was the propounder, and Spallanzani the promulgator. Yet how monstrous for us to believe, that the first female had within her the germs of all mankind born, and to be born; or to conceive, that a grain of Indian corn contains within it all the seed, that may hereafter result from its culture. In this strange hypothesis—as Professor Elliotson[2] observes—there must have been an uncommon store of germs prepared at the beginning, for the ovaria of a single sturgeon have contained 1,467,500 ova.

Many of the ovarists, again, and they alone have any thing like probability in their favour, believe, that the female forms her own ova, as the male forms his own sperm, by a secretory action; and so far as the female is concerned in the generative process, we shall find that this is the only philosophical view; but it is imperfect in not admitting more than a vivifying action in the materials furnished by the male. The view recently advanced by Bischoff,[3] that the spermatozoids act in a catalytic manner,—a certain internal movement being transferred from them to the molecules of the ova, which previously remained dormant,—appears to be liable to the same objections.

[1] Considérat. sur les Corps Organisés, vol. i. & ii., Amst., 1762.
[2] Blumenbach's Physiology, by Elliotson, 4th edit., p. 494, Lond., 1828.
[3] Muller's Archiv. für Anat. No. v. s. 436, Berlin, 1847.

About the middle of the seventeenth century, Hamme or Van Hammen, Leeuenhoek[1] and Hartsöker,[2] discovered a prodigious number of small moving bodies in the sperm of animals, which they regarded as animalcules. This gave rise to a new system of generation, *ab animalculo maris*,—directly the reverse of that of Harvey. As, in the Harveian doctrine, the germ was conceived to be furnished by the mother, and the vivifying influence to be alone exerted by the male; so, in this doctrine, the entire formation was regarded as the work of the father, the mother affording nothing more than a nidus, and appropriate pabulum for the homunculus or rudimental fœtus. The spermatic doctrine was soon embraced by Boerhaave, Keill, Cheyne, Wolff, Lieutaud, and others. The pre-existing germ was accordingly now referred exclusively to the male; and, by some, the doctrine of *emboîtement* or encasing was extended to it. Nor is the view abandoned at the present day; for Dr. Carpenter[3] maintains, that "the male furnishes the germ; and the female supplies it with nutriment, during the whole period of its early developement."

In support of this hypothesis, the spermatists urged,—that the animalcules they discovered were peculiar to the semen, and that they exist in the sperm of all animals capable of generation; that they differ in different species, but are always identical in the same animal, and in individuals of the same species;—that they are not perceptible in the sperm of any animal until the age at which generation is practicable, and are wanting in infancy and decrepitude;—that their number is so considerable, that a drop of the sperm of a cock, scarcely equal in size to a grain of sand, contains 50,000;—and lastly, that their minute size is no obstacle to the supposition, that generation is accomplished by them,—the disproportion between the trees of our forest and the seed producing them being nearly if not entirely as great as that between the animalcule and the being it has to develope. Leeuenhoek estimated the dimensions of those of the frog at about the 1-10,000th part of a human hair, and that the milt of a cod may contain 15,000,000,000,000,000 of them.

The difficulty with the spermatists or animalculists was to determine the mode in which the homunculus attains the ovary, and effects the work of reproduction. Whilst some asserted it to be only requisite, that the sperm should enter the uterus, and attract the ovum to it from the ovarium; others imagined, that the animalcule travelled along the Fallopian tube to the ovary; entered one of the ovarian vesicles; shut itself up there for some time, and then returned into the cavity of the uterus, to undergo its first developement through the medium of the nutritive substance contained in the vesicle; and a celebrated pupil of Leeuenhoek even affirmed, that he not only saw these animalcules under the shape of the tadpole, as they were generally described, but that he could trace one of them, bursting through the envelope that retained it, and exhibiting two arms, two legs, a human head and a heart![4]

[1] Oper. iii. 285, and iv. 169, Lugd. Bat., 1722.

[2] Journal des Sçavans, pour 1678; and Essai de Dioptrique, p. 227, Paris, 1694.

[3] Principles of Human Physiology, 4th Amer. edit., p. 720, Philad., 1850.

[4] Adelon, Physiologie de l'Homme, edit. cit., iv. 94.

This doctrine was extremely captivating; and, for a time, kept the minds of many eminent philosophers in a state of delusive enthusiasm; so much so, that Dr. Thomas Morgan,[1] in a work published in 1731, thus expresses himself regarding it:—"That all generation is from animalculum pre-existing in *semine maris*, is so evident in fact, and so well confirmed by experience and observation, that I know of no learned men, who in the least doubt of it." It was soon, however, strongly objected to by many; and the great fact on which it rested—the very existence of the spermatic animalcules—was, and—we have seen—is, strenuously contested. Linnæus[2] discredited the observations of Leeuenhoek. Verheyen denied the existence of the animalcules, and undertook to demonstrate, that the motion, supposed to be traced in them, was a mere microscopic delusion:—whilst Needham[3] and Buffon regarded them as organic molecules. Subsequently, MM. Prévost and Dumas[4] directed their attention to the subject; and their investigations, as on every other topic of physiological inquiry, are worthy of the deepest regard. The results of their examinations led them to confirm the existence of these animalcules, and likewise to consider them as direct agents in fecundation. By means of the microscope they detected them in all the animals, whose sperm was examined by them; and these were numerous. Whether the fluid was observed after its excretion by a living animal, or after death, in the vas deferens or the testicle, animalcules were detected in it with equal facility. They consider these bodies to be characteristic of the sperm, as they found them only in that secretion,—being wanting in every other humour of the body, even in those that are excreted with the sperm, as the fluids of the prostate, and glands of Cowper; and although similar in shape, and size, and in the character of their locomotion in individuals of the same species, they are of various shapes and dimensions in different species. In passing through the series of genital organs they experience no change, being as perfect in the testicle as at the time of their excretion; and the remark of Leeuenhoek, that they are met with apparently of different ages, is unfounded. They were manifestly endowed with spontaneous motion, which gradually ceased, in the course of two or three hours, in the sperm obtained during life by ejaculation, in that taken from the vessels after death, in fifteen or twenty minutes, and in that left in its vessels after death, in eighteen or twenty hours. In farther proof of the position, that these presumed animalcules are the fecundating agents, MM. Prévost and Dumas assert, that they are only met with whilst reproduction is practicable;—that, in the human species, they are not found in infancy or decrepitude; and, in the majority of birds, are only apparent in the sperm at periods fixed for their copulation;—facts which, in their opinion, show, that they are not mere infusory animalcules. MM. Prévost and Dumas affirm moreover, that they appear to be connected with the physiological condition of the animal

[1] Mechanical Practice of Physic, Lond.
[2] Bostock's Physiology, 3d edit., p. 643, Lond., 1836.
[3] New Microscopical Discoveries, Lond., 1745.
[4] Mém. de la Société Physique de Genève, i. 180, and Annales des Sciences Naturelles, tom. i. and ii.

furnishing them;—their motions being rapid or languishing, according as it is young or old, or in a state of health or disease. They state, also, that in their experiments on the ova of the mammiferous animal, they observed animalcules filling the cornua of the uterus, and remaining there alive and moving, until the ovule descended into that organ, when they gradually disappeared; and in favour of the influence of these animalcules they urge—that the positive contact of sperm is necessary for fecundation, and that the aura seminis is totally insufficient;—that the sperm, in twenty-four hours, loses its fecundating property, and it requires about this length of time for the animalcules to gradually cease their movements and perish;—and, lastly, that having destroyed the animalcules in the sperm, it lost its fecundating property. One of these experiments consisted in killing all the animalcules in a spermatized fluid, whose fecundating power had been previously tested, by repeated discharges of a Leyden phial: another consisted in placing a spermatized fluid on a quintuple filter, and repeating this until all the animalcules were retained on the filter; when it was found, that the fluid that passed through had no fecundating power, whilst the portion retained by the filter had; a result which had been obtained by Spallanzani, who found, moreover, that he was capable of effecting fecundation with water in which the papers employed as filters had been washed.

M. Donné[1] has investigated the mode in which the *zoospermes* are affected in blood, milk, the vaginal and uterine mucus in the healthy state, the purulent matter of chancres, and of blennorrhœa, in saliva, urine, &c. He observed them continue to live, and move in certain of those fluids; whilst in others they died instantaneously. For instance, blood, milk and pus did not affect them: in the mucus of the vagina and uterus they generally lived well; but in saliva and urine they died almost instantaneously. He affirms, too, that there are cases in which the mucus of the vagina and uterus acquires properties that are deleterious to them, and is of opinion, that this is one cause of sterility. This deleterious property, according to M. Donné, occasionally resides in the vaginal mucus; but at others, in a still higher degree in the mucus of the uterus: he endeavoured to discover, whether the mucus of the two membranes presented any peculiar characters or signs of disease, and states, that he particularly noticed the excessive acidity of the one, and the marked alkaline character of the other. Independently of its physical characters, the mucus secreted by the vagina as far as the orifice of the os uteri differed from that which flowed from within the cervix uteri by a different reaction. He found the vaginal mucus always acid,—the uterine alkaline, and he thinks, that the deleterious influence exerted on the *zoospermes* is dependent on excess of acidity in the one, and of alkali in the other. All this, however, it need scarcely be said, requires substantiation. Professor Wagner,[2] who has entered at great length into the consideration of the spermatozoids, accords with the general conclusions of M. Donné: some of his experiments, however—instituted for the most part on the sperma-

[1] Gazette Médicale de Paris, No. xxii., 3 Juin, 1837; and Cours de Microscopie, p. 291, Paris, 1845.

[2] Elements of Physiology, translated by Dr. Willis, p. 20, Lond., 1841.

tozoids of the lower animals—led him to different conclusions. He found, for example, that they almost always lived in saliva; and in urine kept warm and not too concentrated. He repeatedly detected them in the urine of persons whom he suspected of masturbation. Dr. John Davy[1] states, that on examining the fluid from the urethra after stool in a healthy man, he always detected spermatozoids in it; and Dr. Robt. Willis,[2] under the same circumstances, and even after the mere evacuation of the bladder, several times discovered spermatozoids in the fluid of the urethra; but the subjects of his observations were never strong or healthy men; they mostly laboured under anomalous nervous symptoms, which, he thinks, were in all likelihood connected with an irritable or disordered state of the vesiculæ seminales and prostatic part of the urethra.

MM. Prévost and Dumas, and Rolando, conjecture, that the spermatozoids form the nervous system of the new being, and that the ovule furnishes only the areolar framework in which the organs are formed; but this is mere hypothesis. All that is demonstrated is the existence of those peculiar bodies in the sperm, and their manifest agency in the generative process; and it is scarcely necessary to remark, that every objection urged against the system of the ovarists, as regards the proofs in favour of an active participation of both sexes in the work of reproduction, are equally applicable to the views of those who refer generation exclusively to the spermatozoids.[3]

Such are the chief theories that have been propounded on the subject of generation. It has been already observed, that the particular modifications are almost innumerable. They may all, however, be classed, with more or less consanguinity, under some of the doctrines enumerated. Facts and arguments are strongly against any view that refers the whole process of formation to either sex. There must be a union of materials furnished by both, otherwise it is impossible to explain the similarity in conformation to both parents, which is often so manifest. Accordingly, this modified view of epigenesis is now adopted by most physiologists;—that at a fecundating copulation, the secretion of the male is united to a material, furnished by the ovary of the female;—that from the union of these elements the embryo results, impressed, from the very instant of such union, with life, and with an impulse to a greater or less resemblance to this or that parent, as the case may be; and that the material furnished by the female is as much a secretion resulting from the peculiar organization of the ovary, as the sperm is from that of the testicle,—life being susceptible, in this manner, of communication from father to child, without there being a necessity for invoking the incomprehensible and revolting doctrine of the pre-existence of germs. This admixture of the materials furnished by both sexes accounts for the likeness that the child may bear to either parent, whatever may be the difficulty in understanding the

[1] Edinburgh Medical and Surgical Journal, vol. i.
[2] Wagner, op. citat., p. 21 (note).
[3] For a history of opinions in regard to the agency of the sperm, see Coste. Histoire Générale et Particulière du Développement des Corps Organisés, p. 335, Paris, 1849.

precise mode in which each acts in the formation of the fœtus. It has been attempted, however, by some, to maintain, that the influence of the maternal imagination during a fecundating copulation may be sufficient to impress the germ within her with the necessary impulse; and the plea has been occasionally urged in courts of justice. Of this we have an example in a well-known case, tried in New York, between 30 and 40 years ago. A mulatto woman was delivered of a female bastard child, which became chargeable to the authorities of the city. When interrogated, she stated that a black man of the name of Whistelo was the father, who was accordingly apprehended for the purpose of being assessed with the expenses. Several physicians, who were summoned before the magistrates, gave it as their opinion, that it was not his child, but the offspring of a white man. Dr. S. Mitchill, however, who, according to Dr. Beck, seemed to be a believer in the influence of the imagination over the fœtus, thought it probable that the negro was the father. Owing to this difference of sentiment, the case was carried before the mayor, recorder, and several aldermen. It appeared in evidence, that the colour of the child was somewhat dark, but lighter than the generality of mulattoes, and that its hair was straight, and had none of the peculiarities of the negro race. The court very properly decided in favour of Whistelo, and of course against the testimony of Dr. Mitchill, who, moreover, maintained, that as alteration of complexion has occasionally been noticed in the human subject,—as of negroes turning partly white,—and in animals, this might be a parallel instance.[1] The opinion does not seem, however, entitled to much greater estimation than that of the poor Irishwoman, in a London police report, who ascribed the fact of her having brought forth a thick-lipped, woolly-headed urchin to her having eaten some black potatoes during her pregnancy!

It is obvious, that the effect of the maternal imagination can only be invoked—by those who believe in its agency on the future appearance of the fœtus—in the case of animals in which copulation is a part of the process. Where the eggs are first extruded and then fecundated, all such influence must be out of the question; and even in the viviparous animal we have seen that experiments on artificial impregnation have shown, not only that the bitch has been fecundated by sperm injected into the vagina, but that the resulting young have resembled the dog, whence the sperm had been obtained.[2]

But the strongest case in favour of the influence of the maternal imagination is given by Sir Everard Home.[3] An English mare was covered by a quagga,—*Equus quaccha*,—a species of wild ass from Africa, which is marked somewhat like the zebra. This happened in the year 1815, in the park of Earl Morton, in Scotland. The mare was only covered once; went eleven months, four days, and nineteen

[1] Beck's Medical Jurisprudence, 6th edition, i. 500, Philad., 1838. For some ridiculous stories of this kind, see Demangeon, Du Pouvoir de l'Imagination sur la Physique et le Moral de l'Homme, p. 201, Paris, 1834.

[2] See page 424 of this volume.

[3] Philosoph. Transact. for 1821, p. 21; and Lectures on Comparative Anatomy, iii. 307.

hours, and the produce was a hybrid, marked like the father. The hybrid remained with the dam for four months, when it was weaned and removed from her sight. She probably saw it again in the early part of 1816, but never afterwards. In February, 1817, she was covered by an Arabian horse, and had her first foal—a filly. In May, 1818, she was covered again by the same horse, and had a second. In June, 1819, she was covered again, but this year missed: in May, 1821, she was covered a fourth time, and had a third;—all being marked like the quagga. Haller[1] remarks, that the female organs of the mare seem to be corrupted by the unequal copulation with the ass, as the young foal of a horse from a mare, which previously had a mule by an ass, has something asinine in the form of its mouth and lips; and Becher[2] says, that when a mare has had a mule by an ass, and afterwards a foal by a horse, there are evidently marks, in the foal, of the mother having retained some ideas of her former paramour—the ass; whence such horses are commended on account of their tolerance and other similar qualities. It has even been affirmed, that the human female, when twice married, occasionally bears children to the second husband, which resemble the first in bodily structure and mental powers.[3] The mode in which the influence is exerted, in this and similar cases, is unfathomable; and the fact itself, although indisputable, astounding. Sir Everard Home[4] thinks, that it is one of the strongest proofs of the effect of the mind of the mother upon her young that has ever been recorded. Although we are totally incapable of suggesting any satisfactory solution, it appears more probable, that the impression must have been made on the genital system, and probably on the ovaria, rather than on the mind of the animal. Yet it must be admitted, that even this explanation does not well account for a case, recorded by a recent writer.[5] When Dr. Hugh Smith, of England, was travelling in the country, the dogs, as is customary, ran out and barked as he passed through a village, and amongst these he observed a little ugly cur, "that was particularly eager to ingratiate himself with a setter bitch that accompanied him. While stopping to water his horse he remarked how amorous the cur continued, and how courteous the setter continued to her admirer." Provoked at the sight, he shot the cur, and carried the bitch on horseback for several miles. "From that day, however, she lost her appetite; ate little or nothing; had no inclination to go abroad with her master, or to attend to his call; but seemed to pine like a creature in love, and express sensible concern for the loss of her gallant. Partridge came; but Dido had no nose. Some time after, she was put to a setter of great excellence, which had, with great difficulty, been procured for the purpose; yet not a puppy did Dido bring forth, which was not the picture and colour of the cur, that the Doctor had,

[1] Element. Physiol., lib. xxix. sect. ii. § 10, Bern., 1766.
[2] Physic. Subterran., Lips., 1703.
[3] See Art. Generation, by Dr. Allen Thomson, Cyclop. Anat. and Physiol., part xiii., p. 468, for Feb., 1838.
[4] Lectures, &c., iii. 308.
[5] J. S. Skinner, The Dog and the Sportsman, p. 19, Philad., 1845.

many months before, destroyed; and in many subsequent litters, Dido never produced a whelp that was not exactly similar to the unfortunate cur already mentioned!"

The whole of this subject, as well as that of hybridity, is full of interest to the physiologist, and has recently been subjected to fresh investigation. The case of the quagga is a striking one, and the more so as it occurred in animals of different species. Many cases, however, have been observed, in which mares, covered in every instance by different horses, brought forth foals, which always partook of the characters of the horse by which impregnation was first effected. In several foals in the Royal stud at Hampton Court, got by the horse Actæon, there were unequivocal marks of the horse Colonel,—the dams of these foals having been bred from by Colonel the previous year. Again; a colt, the property of the Earl of Sheffield, got by Laurel, so resembled another horse, Camel, that it was asserted at New Market, that he must have been got by Camel. It was ascertained, however, that the mother of the colt had been covered the previous year by Camel.[1] In the dog, sow, and cattle, these phenomena have been often observed; and additional facts have been brought forward to show, that the same thing may happen in the human species; but all observation sufficiently demonstrates that if it ever occurs it must be rare. Dr. Harvey[2] has given two cases in support of the view; one of them that of a woman who was twice married, and had issue by both husbands. The children of the first marriage were five in number; of the second, three. One of these three, a daughter, bears an unmistakeable resemblance to her mother's first husband; and, what makes the likeness the more striking, there was the most marked difference between the two husbands in their features and general appearance.

The phenomena of hybridity have been referred to before. It is undoubtedly a general rule, that hybrids do not procreate. Buffon, Mr. Hunter, and others, indeed, considered the rule absolute; but it is not admitted to be a test of specific character. Dr. Morton[3] has enumerated various forms of hybridity in animals and plants; and has shown, that it occurs, not only amongst different species, but amongst different genera; and that the cross breeds have been prolific in both cases. There is great probability, that if animals were so situate, that the want of inclination for each other, or the natural repugnance could be overcome, so that sexual desire should arise, cases of hybridity would be much more frequent than they are. In the year 1848, a remarkable filly—seven months old—was found in the New Forest, England, which is evidently—from the sketch of it[4]—a mixed breed between the horse and the deer. The mother—a pony mare, was observed to associate with some red deer stags, and at length the

[1] McGillivray, Aberdeen Journal, Mar. 28, 1849; quoted by Dr. Alexander Harvey, in Monthly Journal of the Medical Sciences, Oct., 1849.

[2] Op. cit.

[3] Hybridity in animals and plants, considered in reference to the question of the unity of the human species, New Haven, 1847, from Amer. Journ. of Science and Arts, vol. iii., second series, 1847.

[4] Illustrated London News, Dec. 9, 1848.

foal in question was seen by her side. The nose shows an approximation both to the stag and the horse; the forehead is round like that of the deer; the legs are slender and distinctly double; and the hoofs pointed, and partly double; the colour is brown, lighter under the belly; and the tail is like that of the deer.

In cases of infertile or barren hybrids, there would appear to be a radical change produced in the germ-forming organs of both sexes. Of the modifications in the female genital system we know nothing. In the male, in many cases, there does not seem to be any spermatozoids in the semen. Such has been shown to be the case with the mule by Bonnet, Prévost and Dumas, Hausmann and others; and the same thing has been observed in the hybrids of goldfinches and canary birds.[1] In others, real spermatozoids have been seen, but they were smaller and shaped differently than the natural. The sperm of procreating hybrids does not appear to have been examined.

The fact, that various different species of animals are capable of producing a prolific hybrid is fatal—as Dr. Morton[2] has remarked—to the notion, that hybridity is "a test of specific affiliation;" and, "consequently,"—he adds—"the mere fact, that the several races of mankind produce with each other a more or less fertile progeny, constitutes, in itself, no proof of the unity of the human species."

It has been a common opinion, not confined to the vulgar only, that the mulatto is not as fertile as the white or the negro; and the probable extermination of the two races has been suggested, if the whites and blacks were allowed to intermarry;[3] but the assertion can scarcely be esteemed to rest on sufficient actual observation. Were it so, it might be interesting to inquire, whether the infertility applies rather to the female than to the male. It would probably be found, that the former would be in fault. It is affirmed by an excellent and talented traveller,[4] with whom the author had the pleasure of a personal acquaintance in this country, that examinations among the oldest aborigines of every country render it evident "that their longevity has not been abridged; that the rate of mortality has not increased, but that the power of continuing or procreating the species appears to have been curtailed. On further inquiry, this curtailment of power was not found to originate with the male, so far at least as could be observed; but some startling facts, disclosed in the course of the investigation, seem to confine it to the female." Of these the most remarkable, according to Count Strzelecki, is, that whenever a union takes place between an aboriginal female and a European male, "the native female is found to lose the power of conception on a renewal of intercourse with the male of her own race, retaining only that of procreating with the white man." "Hundreds of instances"—he adds—"of this extraordinary fact are on record in the writer's memoranda, all tending to

[1] Art. Semen, Cyclopædia of Anatomy and Physiology, B. xxxiv. p. 508, Jan., 1849.
[2] Op. cit., p. 23.
[3] J. C. Nott, American Journal of the Medical Sciences, July, 1843, p. 252.
[4] P. E. de Strzelecki, Physical Description of New South Wales and Van Diemen's Land, p. 346, London, 1845.

prove, that the sterility of the female being relative only to one, and not to another male,—and recurring invariably, under the same circumstances, amongst the Hurons, Seminoles, Red Indians, Yakies (Sinaloa), Mendoza Indians, Araucos, South Sea Islanders, and natives of New Zealand, New South Wales, and Van Diemen's Land,—is not accidental, but follows laws as cogent, though as mysterious, as the rest of those connected with generation."

These statements are worthy of every attention, but they require fresh investigations before they can be regarded as established, especially as they certainly do not apply to the negro,—repeated opportunities occurring in this country and elsewhere to show, that the impregnation of a coloured woman by a white man does not deprive her of the power of subsequent procreation with an individual of her own race.

d. *Conception.*

Conception usually takes place without the slightest consciousness on the part of the female; hence the difficulty of reckoning the precise period of gestation. Certain signs, as shivering, pains about the umbilicus, &c., are said to have occasionally denoted its occurrence; but they are rare exceptions, and the indications afforded by one female are often extremely different from those presented by another. In animals, in which generation is only accomplished during a period of generative excitement, the period of conception can be determined with accuracy; for, in by far the majority of such cases, a single copulation fecundates, —the existence of the state of *heat* indicating, that the generative organs are ripe for conception. In the human female, where sexual intercourse can take place at all periods, conception is by no means as likely to follow a single intercourse; for, although she may be always susceptible of fecundation, her genital organs are rarely, perhaps, so powerfully excited as in the animal during the season of love. It is not for the physiologist to inquire into the morbid causes of sterility in either male or female; nor is it desirable to relate all the visionary notions which have prevailed regarding the circumstances that favour conception. The ovarian conditions under which it is effected have already been canvassed under Fecundation.

It has been attempted to ascertain what age and season are most prolific. From a register kept by Dr. Bland, of London, it would appear, that more women bear children between the ages of twenty-six and thirty years, than at any other period. Of two thousand one hundred and two women delivered, eighty-five were from fifteen to twenty years of age; five hundred and seventy-eight from twenty-one to twenty-five; six hundred and ninety-nine from twenty-six to thirty; four hundred and seven from thirty-one to thirty-five; two hundred and ninety-one from thirty-six to forty; thirty-six from forty-one to forty-five; and six from forty-six to forty-nine. At Marseilles, according to Raymond, women conceive most readily in autumn, and especially in October; next in summer; and lastly in winter and spring,—the month of March having fewest conceptions. Morand says, that July, May, June, and August have the most; and November, March, April, and

October, successively, the fewest. At the Havana, according to tables by the author's friend, Don Ramon de la Sagra,[1] the monthly number of births, amongst the white population, during a period of five years,—from 1825 to 1829 inclusive—was in the following order:—October, September, November, December, August, July, June, April, May, January, March, and February. February, January, March, and April are, therefore, the most favorable for conception at the Havana; June, July, May, and September the least so. Dr. Burns[2] asserts, that the register for ten years of an extensive parish in Glasgow, renders it probable that August and September are most favourable. M. Villermé, from an estimate founded on eight years' observations in France, comprising 7,651,437 births, makes the ratio as follows:—May, June, April, July, February, March and December, January, August, November, September, and October:—and Dr. Gouverneur Emerson,[3] who has employed himself most profitably on the Medical Statistics of Philadelphia, has furnished a table of the number of births, during each month, for the ten years ending in 1830; according to which, the numbers are in the following order: December, September, January, March, October, August, November, February, July, May, April, and June,—the greatest number of conceptions occurring, consequently, in April, January, and May,—the least in October, August, and September.

The proportion will, of course, be regulated to a great extent by the time of marriage. In England,[4] the greatest number of these occurs in autumn, and consequently we should expect the ratio of births to be greatest in winter, which is the fact. The following table shows the relative number of marriages, births, and deaths, in the seasons of the year, corrected for inequality of time.

	Autumn.	Spring.	Summer.	Winter.
Marriages, - - - - -	36,306	31,355	29,634	25,482
Births, - - - - -	131,257	129,677	121,053	120,356

The human female is uniparous,—one ovum only, as a general rule, being fecundated: numerous other animals are multiparous, or bring forth many at a birth. The law on this subject is not fixed, however. Occasionally, the human female brings forth twins, triplets, or quadruplets; and the multiparous animal is not always delivered of the same number. It is impossible to account for those differences. The ovarists refer them to the female; the animalculists to the male; and facts have been found to support both views. Certain females, who have been frequently married, have been multiparous with each husband; and analogous facts have occurred to males under similar circumstances. Ménage cites the case of a man, whose wife brought him twenty-one children in seven deliveries; and the same individual having impregnated his servant-maid, she brought forth triplets likewise. It is asserted, that, in 1755, a peasant was presented to the Empress of Russia, who was seventy years of age, and had been twice married.

[1] Historia Economico-Politica y Estadistica de la Isla de Cuba, Habana, 1833.
[2] Principles of Midwifery, 3d edit., p. 126, London, 1814.
[3] Amer. Journ. of the Med. Sciences, for Nov., 1831.
[4] Fifth Annual Report of the Registrar-General, &c., London, 1843.

His first wife had fifty-seven children at twenty-one births. In four deliveries she had four children at each; in seven, three; and in six, two. This appears to be the *ne plus ultra* of such cases!

In the *Hospice de la Maternité*, of Paris, it has been observed, that twins occur once in about eighty cases. In the Westminster Hospital, the same ratio has been found to prevail. In 1840, of 547,293 births in the kingdom of Prussia, 6,381 were twin cases, or 1 in 90. In the British Lying-in Hospital, the proportion was not greater than 1 in 91; whilst in the Dublin Lying-in Hospital, the cases were nearly twice as frequent, or about 1 in 57. Dr. Collins[1] remarks on the singular circumstance, that in Ireland the proportional number of women giving birth to twins, is nearly a third greater than in any other country of which he had been able to obtain authentic records. He states the proportion in France to be *one* in 95 births; in Germany, *one* in 80; in England, *one* in 92; in Scotland, *one* in 95; and in Ireland, *one* in 62. According to the report of Dr. Simpson[2] of the Edinburgh Royal Maternity Hospital, among 1417 women delivered, 17, or 1 in 83, gave birth to twins. Of 129,172 women delivered in the Lying-in Hospital, Dublin, 2062 gave birth to twins; 29 produced three at a birth, which is in the proportion of *one* in 4450; and *one* only gave birth to *four*. In this country, the average of twin cases, according to Dr. Dewees, is about 1 in 75. Triplet cases were found to occur in the *Hospice de la Maternité*, of Paris, about once in 9000 times; and in the Dublin Hospital once in 5050 times; the balance, again, being largely in favour of the prolific powers of the Irish. Dr. Dewees affirms, that in more than 9000 cases, he had not met with an instance of triplets. Of 36,000 cases in the *Hospice de la Maternité* not one brought forth four children. In 1849, a woman, a native of Ireland, living in Southwark, Philadelphia, was delivered of four children,—all boys, each weighing about five pounds:—three of them were born alive. This woman, who was about 19 years of age, is said to have had six children by a former husband at three parturitions. At the first, she was delivered of a boy and a girl; at the second of a girl, and at the third of two boys and a girl. There are cases on record where five have been born. Beyond this number the tales of authors ought perhaps to be esteemed fabulous. The statistics of the Lying-in Hospital of Vienna and of Belgium, that have reference to this subject, are given hereafter.

On inspecting the following table, it will be found to be a general rule amongst quadrupeds, that the largest and most formidable bring forth the fewest young, and that the lower tribes are unusually fruitful, —the number produced compensating, in some measure, for their natural feebleness, which renders them constantly liable to destruction. On the other hand, were the larger species to be as prolific as the smaller, the latter would soon be blotted from existence. What would have been the condition of animated nature, if the gigantic mastodon, once the inhabitant of our plains, could have engendered as frequently and as numerously as the rabbit! For wise purposes, it has been or-

[1] A Practical Treatise on Midwifery, London, 1835: republished in Bell's Select Library Philad., 1838.

[2] Monthly Journal and Retrospect of the Medical Sciences, Nov. 1848, p. 334.

dained, that the more formidable animals seldom begin the work of reproduction until they have nearly attained their full size; whilst those that bring forth many commence much earlier. Lastly, there is some correspondence between the duration of gestation and the size of the animal.

Animals.	Duration of Gestation.	Number of Young.	Animals.	Duration of Gestation.	Number of Young.
Ape	about 9 months,	1	Lioness	. . .	4 or 5
Bat	. . .	2	Tigress	. . .	4 or 5
Rat	5 or 6 weeks,	5 or 6	Cat	8 weeks,	4 or 5
Mouse	. . .	6 to 10	Seal	. . .	2
Hare	30 days,	4 or 5			
Rabbit	Do.	Do.	Mare	11 months and some days,	1
Guinea-pig	3 weeks,	5 to 12			
Squirrel	6 weeks,	4 or 5	Ewe	5 months,	1 or 2
Mole	. . .	4 or 5	Goat	$4\frac{1}{2}$ months,	1, 2, or 3
Bear	. . .	2 or 3	Cow	9 months,	1 or 2
Otter	9 weeks,	4 or 5	Reindeer	8 months,	2
Bitch	9 weeks,	4 to 10	Hind	Do.	1 or 2
Ferret	6 weeks,	6 or 7	Sow	4 months,	6 to 12 and more
Wolf	10 weeks,	5 to 9			
Opossum	. . .	4 or 5	Camel	12 months,	1
Kangaroo	. . .	1	Walrus	9 months,	1
Jackall	. . .	6 to 8	Elephant	2 years,	1
Fox	10 weeks,	4 or 5	Whale	9 or 10 months,	1 or 2

Conception being entirely removed from all influence of volition, it is obviously impracticable, by any effort of the will, either to modify the sex of the fœtus or its general physical and moral characters. Yet idle and absurd schemes have been devised for both one and the other. The older philosophers, as Hippocrates and Aristotle, believed that the right testicle and ovary furnish the rudiments of males, and the same organs, on the left side, those of females: and some of the old writers, *de Re Rusticâ*, assert that such was the result of their experiments with the ram. These statements gave rise to a pretended "art of procreating the sexes at pleasure," which has been seriously revived in our own time. Mr. John Hunter published the details of an experiment in the "Philosophical Transactions," which was instituted for the purpose of determining, whether the number of young be equally divided between the ovaries. He took two sows from the same litter, deprived one of an ovarium, and counted the number of pigs produced by each during its life. The sow with two ovaries had one hundred and sixty-two: the spayed one only seventy-six. Hence he inferred, that each ovary had nearly the same proportion. In this experiment, he makes no mention of the interesting fact regarding the proportion of the males in the two cases, and whether they were all of the same sex in the sow that had been spayed. Had his attention been drawn to this point, the results would doubtless have been sufficient to subvert the strange hypothesis brought forward by M. Millot,[1] that males are produced by the right ovary; females by the left; and the wild assertion, that he could so manage the position of the woman during copulation, that she should

[1] L'Art de Procréer les Sexes a Volonté; nouvelle édit., par M. Breschet, Paris, 1829.

certainly have a boy or girl, as might have been determined upon: in conformation of which he published the names of mothers, who had followed his advice, and succeeded to their wishes! A case, related by Dr. Granville, of London, to the Royal Society,[1] has completely exhibited the absurdity of this notion. A woman, forty years of age, died at the *Hospice de la Maternité* of Paris, six or seven days after delivery, of what had been supposed to be disease of the heart. The body was opened in the presence of Dr. Granville, and the disease was found to be aneurism of the aorta. On examining the uterus, it was discovered to be at least four times the size of the unimpregnated organ. It had acquired its full developement on the right side only, where it had the usual pyriform convexity; whilst the left formed a straight line scarcely half an inch distant from the centre, although it was more than two inches from the same point to the outline of the right side. The Fallopian tube and ovary, with the other parts on the right side, had the natural appearance; but *they were not to be found on the left.* Yet this woman had been the mother of eleven children of both sexes; and a few days before her death had been delivered of twins,—one male and one female.[2] M. Jadelot has given the dissection of a female, who had been delivered of several children—boys and girls; yet she had no ovary or Fallopian tube on the right side. M. Lepelletier[3] asserts, that he saw a similar case in the Hospital at Mans, in 1825; and the *Recueils* of the *Société de Médecine*, of Paris, contain the history of an extra-uterine gestation, in which a male fœtus was contained in the left ovary.

Independently of these decisive cases, it has been found, that when one of the ovaries has been entirely disabled by disease, the other has conceived of both sexes. In rabbits, an ovary has been removed; yet both male and female fœtuses have subsequently been engendered; and if the gravid uterus of one of those animals be examined, male and female fœtuses may be found in the same cornu of the uterus, all of which, owing to peculiarity of construction of the uterus,—the cornu forming the main part of the organ,—must manifestly have proceeded from the corresponding ovary. We are totally unaware, therefore, of the circumstances that give rise to the sex of the new being; although satisfied that it is in no respect influenced by the desires of the parents. We shall see, hereafter, that some distinguished physiologists believe, that the sex is not settled at the moment of conception, and that it is determined at a later period, after the embryo has undergone a certain degree of developement.

It is an ancient opinion, which seems to be in some measure confirmed by what we notice in certain animals, that the character of the offspring is largely dependent upon the moral and physical qualities of the parent; and a M. Robert, of Paris, in a dissertation under the pompous title of *Megalanthropogenesis*, has fancifully maintained, that the race of men of genius may be perpetuated by uniting them to women possessed of the same faculties. Similar views are maintained

1 Philos. Transact. for 1808, p. 308. 2 Sir E. Home, Lect. on Comp. Anat. iii. 300.
3 Physiologie Médicale et Philosophique, iv. 333, Paris, 1833.

by Claude Quillet.[1] It is an old view, that the procreative energy of the parents has much to do with the mental and corporeal activity of the offspring. Hence it is, that bastards have been presumed to excel in this respect. Such is the view of Burton,[2] and the same idea is put, by Shakspeare, into the mouth of Edmund.

> "Why brand they us
> With base? with baseness? bastardy? base? base?
> Who in the lusty stealth of nature take
> More composition and fierce quality
> Than doth within a dull, stale, tired bed
> Go to the creating a whole tribe of fops
> Got 'tween sleep and wake!"—KING LEAR, i. 2.

Much doubtless, depends upon the condition of the parents as regards their organization and strength of constitution. The remark—"fortes creantur fortibus et bonis"—is true within certain limits; but we have no proof, that the ardour of the procreative effort can have any such influence; and the ratio of instances of bastards, who have been signalized for the possession of unusual vigour—mental or corporeal—to the whole number of illegitimates, is not greater than in the case of those born in wedlock. It has been stated that the number of male children is greater in cases of legitimate than of illegitimate births. Mr. Babbage[3] has compared the ratio in different countries, from which he has formed the following table:—

	Legitimate Births.		Number of Births observed.	Illegitimate Births.		Number of Births observed.
	Females.	Males.		Females.	Males.	
France,	10,000	10,657	9,656,135	10,000	10,484	673,047
Naples,	10,000	10,452	1,059,055	10,000	10,267	51,309
Prussia,	10,000	10,609	3,672,251	10,000	10,278	212,804
Westphalia,	10,000	10,471	151,169	10,000	10,039	19,950
Montpellier,	10,000	10,707	25,064	10,000	10,081	2,735
Mean,	10,000	10,575		10,000	10,250	

Of 248,544 children registered in England,[4] 15,389 were illegitimate; so that 1 in 16 of the children born in England is not born in wedlock. In Austria, in the year 1843, 1 child in 4 was illegitimate; and in Vienna, 1 in 2.[5]

From the statistics of the Gebäranstalt, the Imperial Lying-in Hospital of Vienna, which is the great receptacle of illegitimate conceptions, it would seem that the number of female children born in it actually exceeds that of males. Of 21,212 children born there in the seven years prior to 1838, the sexes were in the proportion of

[1] Callipædia, sive de Pulchræ Prolis Habendæ Ratione, &c., Lond., 1708.
[2] Anatomy of Melancholy, vol. ii.
[3] Brewster's Journal of Science, New Series, No. 1.
[4] Fifth Annual Report of the Registrar-General of Births, Deaths, and Marriages, in England, Lond., 1843.
[5] Knolz, Jahresbericht, u. s. w. in der Provinz Oesterreich unter der Enns, vom Jahre, 1843, s. xlix. Wien, 1844.

10,584 males to 10,628 females.[1] It is proper, however, to remark, that the Registrar-General found the reverse of this to be the fact in England.[2] Of the legitimate births, the boys were to the girls as 105·4 to 100·0; whilst of the illegitimate, they were as 108·0 to 100·0. "It is, I believe, assumed"—he remarks—"in the French returns, that foundling children are illegitimate. If it be true, as is stated by those acquainted with the matter, that many of the children sent to the foundling hospitals in France are the offspring of married people, who probably abandon a greater proportion of girls than boys, it will follow;—*first*, that the proportion of children born out of wedlock is nearly the same in England as in France; and, *secondly*, that the inference from the returns of Continental States having foundling hospitals as to the relative predominance of females among natural children is fallacious." It is obvious, that these authoritative statistical conclusions must make us pause before we can regard it as at all established, that the ratio of boys to girls is less amongst illegitimate than legitimate conceptions.

To elucidate the effect of the condition of the parent on the future progeny, M. Girou de Buzareingues[3] gave a violent blow to a bitch whilst lined; in consequence of which she was paraplegic for some days. She brought forth eight pups, all of which, except one, had the hind legs wanting, malformed, or weak. It has been attempted to show, also, that the corporeal vigour of the parents has much to do even with the future sex. M. Girou instituted a series of experiments on different animals, but especially on sheep, to discover, whether a greater number of male or female lambs may not be produced at the will of the agriculturist. The plan adopted to insure this result, was to employ very young rams in that division of the flock where it was desired to obtain females; and strong and vigorous rams, of four or five years of age, in that from which males were to be procured. The result would seem to show, that the younger rams begat females in greater proportion; and the older, males. M. Girou asserts, that females commonly predominate amongst animals that live in a state of "polygamy," and it is affirmed, that the same fact has been observed, in Turkey and Persia, in the human species; but statistical data are wanting. These and other facts have seemed, however, to show, that in the act of generation, it is, as a general rule, the stronger individual that regulates the sex of the progeny. M. Moreau[4] has arrived at this conclusion as the result of long observation. He is of opinion, that, to a certain extent, a boy or girl may be begotten at will by strengthening or weakening the father or mother, previous to the act of generation; and he states, that by acting on this rule he has seen, in numerous instances, his advice followed by the desired results.

From the researches of Hofacker[5] and Sadler,[6] it would appear, that,

[1] Austria: its Literary, Scientific, and Medical Institutions, by W. R. Wilde, p. 22, note, Dublin, 1843.

[2] Fifth Annual Report, &c., Lond., 1843.

[3] Mémoire sur les Rapports des Sexes, &c., Paris, 1836; and a farther Memoir, in Revue Médicale, 1837.

[4] Edinb. Med. and Surg. Journ., Oct., 1844; from L'Expérience, 4 Juillet, 1844.

[5] Annales d'Hygiène, p. 537, July, 1829.

[6] The Law of Population, ii. 343, Lond., 1830.

as a general rule, when the mother is older than the father, fewer boys are born than girls, and the same is observed where they are of equal age; but the greater the excess of age on the part of the father, the greater will be the ratio of boys. The fact deduced from the observations of these gentlemen has been characterized by a recent writer as "one of the most remarkable contributions that have yet been made by statistics to physiology."[1] The following table gives the average results obtained by them; the numbers indicating the proportion of male births to 100 females.

	Hofacker.		Sadler.
Father younger than mother,	90·6	Father younger than mother,	86·5
Father and mother of equal age,	90·0	Father and mother of equal age,	94·8
Father older by 1 to 6 years,	103·4	Father older by 1 to 6 years,	103·7
6 to 9	124·7	6 to 11	126·7
9 to 18	143·7	11 to 16	147·7
18 and more,	200·0	16 and more,	163·2

Recent researches by Dr. Emerson,[2] have led him to the conclusion, that the extensive prevalence of every severe zymotic disease; and indeed any occurrence, which directly or indirectly exerts a decidedly depressing effect upon a community, will be indicated in the record of births, by a conspicuous reduction in the proportion of males. The ordinary average excess of male births was found, by former calculations, to be, in Philadelphia, about 7 per cent.; and during the cholera months of August and September, 1832, the diminution of male conceptions was at the rate of more than 17 per cent.; and a similar diminution occurred in Paris, and other places, during the existence of the same malady.

It appears, that the general proportion of males born to females is every where pretty nearly the same. The calculations of Hufeland give the numbers in Germany as 21 to 20; those of Girou, in France, as 21 to 19·69; and in Paris, 21 to 20·27; the census of Great Britain, taken in 1821, estimates it as 21 to 20·066, and the Registrar-General of England,[3] at 21 to 20·026. In the Dublin Lying-in Hospital during ten years, the ratio was 21 to 19·33; in the Eastern District of the Royal Maternity Charity of London, during the year 1830, 21 to 19·64; and in the province of Austria, in the year 1823,[4] 21 to 20. In Philadelphia, according to the tables of Dr. Emerson,[5] the proportion from 1821 to 1830, was 21 to 19·43. In the whole of Europe it is estimated to be 21 to 19·81. Although, however, a greater number of males may be born, they seem more exposed to natural or accidental death; for amongst adults the balance is much less in their favour; and, indeed, the number of adult females rather exceeds that of the males. Dr. Emerson[6] states, that of the children born in Philadelphia during the ten years included between 1821 and 1830, amounting,

[1] Carpenter, Human Physiology, § 771, Lond., 1842.
[2] American Journal of the Medical Sciences, for July, 1848, p. 78.
[3] Fifth Annual Report of the Registrar-General of Births, Deaths, and Marriages in England, Lond., 1843.
[4] Knolz, op. cit.
[5] Amer. Journ. of the Med. Sciences, for Nov., 1835.
[6] Ibid., for Nov., 1835, p. 56.

according to the returns made to the Board of Health, to 64,642,—there were 2,496 more males than females. But, notwithstanding the males at birth exceeded the females about $7\frac{1}{2}$ per cent., the census of 1830 shows, that by the fifth year, the male excess is reduced to about 5 per cent., and at ten years to only 1 per cent.; and that, the reduction still going on, the number of females between the ages of 10 and 15 exceeds that of the males about 8 per cent.; and between 15 and 20, 7·3 per cent.; facts, which clearly authorize the deduction of M. Quetelet,[1] that during the early stages of life there are agencies operating to reduce the proportion of the male sex. Dr. Emerson's investigations exhibit clearly, that the greater liability of males to accidents did not furnish a sufficient reason for their greater mortality;—the deaths, reported in the Philadelphia bills, under the head of casualties, constituting but a small proportion of the whole mortality; and this—when burns and scalds are included—being more considerable in the case of the female. The gross male mortality under the twentieth year, for the ten years above mentioned, exceeded the female mortality in the ratio of 7·94 per cent. The diseases, which seemed to be particularly obnoxious to the male sex, were, according to the Philadelphia bills, the following—arranged in the order of their decreasing mortality:—inflammation of the brain, inflammation of the bowels, bronchitis, croup, inflammation of the lungs, fevers of all kinds (except scarlet), convulsions, general dropsy, dropsy of the head, and small-pox. To these sources of mortality may be added those under the head of casualties, and others vaguely designated debility, decay, &c. The few cases in which the deaths of females predominated were,—consumption, dropsy of the chest, scarlet fever, burns and scalds, and hooping-cough. In subsequent statistical researches on this interesting topic, Dr. Emerson[2] found, that in Philadelphia, the diseases, which prove especially fatal to male children, are—inflammation of the brain and its consequences, convulsions and hydrocephalus, inflammation of the lungs, stomach, bowels, &c., and fevers of all kinds,—some of the eruptive excepted. On the other hand, the diseases in which the deaths of female children preponderate are few in number,—the chief being hooping-cough, scarlet-fever, and consumption; whence he concludes, that the maladies most fatal to male children seem to be of the sthenic class,—to females, of the asthenic.

It would appear, that on the average, about one infant in twenty is still-born. The cause of this is a difficult inquiry; as well as that of the greater ratio—double—in cities than in the country; in some cities than in others; amongst male infants rather than females; in winter than in summer; and amongst the illegitimate rather than the legitimate. It is an interesting topic of investigation for the medical statistician. The following table, embracing the statistics of the Imperial Lying-in Hospital of Vienna, which, as before remarked, is the great receptacle for illegitimate conceptions, is interesting on account of the number of cases observed. It is given by Mr. Wilde,[3] of Dublin, who

[1] Sur l'Homme, i. 156, Paris, 1835.
[2] Amer. Journ. of the Med. Sciences, for Jan., 1846, p. 92.
[3] Op. cit., p. 223.

states, that it was collected and arranged with much care from the unpublished records of the hospital for the eight years ending Dec. 31, 1840, and exhibits the results of 25,906 deliveries, and 26,149 births.

NUMBER OF DELIVERIES, 25,906.

Children,	Single births,	25,638	
	Twins, 248 times,	496, or 1 in 105·43	
	Triplets, 5 "	15, or 1 in 5229·8	
	Total births,	26,149	
Sex in 23,413 births,	Boys, 11,717; Girls, 11,696	Proportion of Males to 100 Females,	100·17
Sex of still-born children in 2201 births,	Boys, 48; Girls, 45; Total, 93	Proportion of Males to 100 Females,	106·66
Total still-born in 23,413 births,		939, or 1 in 24·92	
Died before the ninth day in 23,222,		1482, or 1 in 15·66	
Sexes in 95 of these,	Boys, 49; Girls, 46	Proportion of Males to 100 Females,	106·52
Abortions and premature deliveries in 25,705,		674, or 1 in 38·13	

It will be observed, that the ratio of still-born is smaller than the average; yet it is much higher than in the whole of the Austrian dominions, in which the proportion, according to Mr. Wilde, was 1 in 30·62; and according to Knolz,[1] in 1843, in the province of Austria, 1 in 36·4. It is difficult, however, to believe, that Mr. Wilde's statistics can be accurate, when we observe the ratio in Linz stated to be 1 in 155·35 only![2] If all the statistical observations be esteemed accurate, they certainly exhibit a great and inexplicable difference in countries on all these topics. The official records of Belgium,[3] for example, give the number of still-born legitimate males to that of still-born legitimate females as 1·39 to 1; whilst the ratio of still-born illegitimate males to females is only 1·14 to 1. The legitimate males born alive were to the females in the ratio of 1·05 to 1; the illegitimate of 1·04 to 1. The following was the proportion of single births, of the born alive, of the still-born, and of twins to the whole number of births, including the still-born, in four successive years:—

	1841	1842	1843	1844
Single births,	1 in 1·02	1·02	1·02	1·02
Born alive,	1 in 1·04	1·04	1·04	1·04
Born dead,	1 in 25·97	25·67	24·09	23·76
Twins,	1 in 58·38	54·88	53·44	52·40

In 1841, there were 9 triple births (8 boys and 19 girls); in 1842, 16 (25 boys and 23 girls); in 1843, 10 (11 boys and 19 girls); and in 1844, 11 (20 boys and 13 girls). In 1842, there was one quadruple birth (all females); and in 1844, there were 2 (2 males and 6 females).

A statistical contribution to obstetrical physiology has been made by Professor J. Y. Simpson, of Edinburgh,[4] which is full of interest in this relation. From elaborate tables contained in Dr. Collins's Treatise on Midwifery, he deduces the following propositions. *First.*

[1] Op. cit. [2] Ibid., 225.

[3] Statistique de la Belgique.—Population, Mouvement de l'Etat Civil pendant l'Année 1844, p. vi., Bruxelles, Novemb., 1845.

[4] Edinb. Med. and Surg. Journal, Oct., 1844.

That the dangers and difficulties of parturition are greater to the mother in male than in female births. *Secondly*. That the dangers and accidents from parturition and its results are greater to the child in male than in female births: and *Thirdly*. That for the very marked difference between the difficulties and perils, both to the child and the mother, in male, from that which exists in female births, there is no other traceable cause in the mechanism of parturition, except the larger size of the head of the male child.

The records of the Dublin hospital showed, that there died during the process of parturition, "and probably as a consequence of the injuries to which they were subjected," 151 male children for every 100 female. There was thus an excess of 50 male deaths in every 250 children, or 20 in every 100;—referable, according to Dr. Simpson, to the greater size of the head of the male infant. "Further," he adds, "we may take it for granted, that, on a low computation, 1 in every 50 children born dies during labour, about 1 in every 25 cases being a still birth. To be certain, however, not to overstep our limits, let us reckon only 1 in every 75 children to die during parturition, and 1 in every 5, or 20 per cent. of those that thus perish, to be formed by that excess of mortality of males over females, which we can trace to no other cause than the influence of the greater dimensions of the male head. In England and Wales about 500,000 births take place annually. By the above computation, more than 6500 of the offspring of these births die during labour, and one-fifth of that number are lost in consequence of the sex and size of the male child. In Great Britain, therefore, the lives of 15,000 infants are annually lost in childbirth, from the operation of this agency."

Applying a similar mode of reasoning to account for the excess of male infants, who die within the first year after birth, Dr. Simpson concludes, that there perish annually in Great Britain, upwards of 5000 children within the first year after birth, whose death is referable to the influence of the sex, and greater size of the male head during labour.

e. *Superfœtation.*

It has been an oft-agitated question, whether, after an ovule has been impregnated and passed down into the cavity of the uterus, another ovule may not be fecundated; so that the products of two conceptions may undergo their respective developements in the uterus, and be delivered at an interval corresponding to that between the conceptions. Many physiologists have believed this to be possible, and have given it the name *superfœtation*. The case, cited from Sir Everard Home, of a young female, who died on the seventh or eighth day after conception, exhibits that the mouth of the womb is at an early period completely obstructed by a plug of impervious mucus—*mucus infranchissable* of M. Pouchet, and that the inner surface of the uterus is lined by an efflorescence of plastic matter, the nature of which will be described under the next head. When such a change has been effected, it would seem to be impossible for the male sperm to reach the ovary; and accordingly, the general belief is, that superfœtation is only practicable

prior to these changes, and when there is a second vesicle ripe for impregnation. Of this kind of *superconception* or *superfecundation* it is probable, that twin and triplet cases are often, if not always, examples;—one ovule being impregnated at one copulation, and another at the next.[1] This seems to be common in animals. The dog-breeders have often remarked, that a bitch, after having been lined, will readily admit a dog of a very different kind to copulate with her; and different descriptions of puppies have been brought forth,—some resembling each of the fathers. Sir Everard Home[2] states, that a setter bitch was lined in the morning by a pointer. The bitch went out with the gamekeeper, who had with him a Russian setter of his own, which also lined her in the course of the afternoon. She had a litter of six puppies; two only of which were preserved. One of these bore an exact resemblance to the pointer; the other to the Russian setter,—the male influence being predominant in each.

Of this kind of superfœtation or double conception we have several instances on record, of which the following are amongst the most striking;—the male parent of the respective fœtuses having differed in colour. The first is the well-known case cited by Buffon[3] of a female at Charleston, South Carolina, who was delivered in 1714 of twins, within a very short time of each other. One of these was black; the other white. This circumstance led to an inquiry, when the woman confessed, that on a particular day, immediately after her husband had left his bed, a negro entered her room, and compelled her to gratify his wishes, under threats of murdering her. Several cases of women in the West India Islands having had, at one birth, a black and a white child, are recorded; and Dr. Moseley[4] gives the following case, which is very analogous to that described by Buffon. A negro woman brought forth two children at a birth, both of a size, one of which was a negro, the other a mulatto. On being interrogated, she said, that a white man belonging to the estate came to her hut one morning before she was up, and that she received his embraces soon after her black husband had quitted her. Sir Everard Home[5] likewise asserts, that a particular friend of his "knows a black woman, who has two children now alive, that are twins and were suckled together; one quite black, the other a mulatto. The woman herself does not hesitate in stating the circumstances; one morning just after her husband had left her, a soldier, for whom she had a partiality, came into her hut, and was connected with her, about three or four hours after leaving the embraces of her husband." One of the author's pupils, Dr. N. J. Huston, then of Harrisonburg, Virginia, also communicated to him the case of a female who was delivered, in March, 1827, of a negro child and a mulatto on the same night. Where negro slavery exists, such cases are sufficiently numerous:[6] two have been recorded recently.[7] So far,

[1] Art. Zwillinge, in Pierer's Anat. Physiol. Real. Wörterb., Band viii., Altenb., 1829.

[2] Lect. on Comp. Anat., iii. 302.

[3] Hist. Nat. de l'Homme, *Puberté.*

[4] A Treatise on Tropical Diseases, p. 111.

[5] Op. cit.

[6] See, for an enumeration of cases, Beck's Medical Jurisprudence, 6th edit., i. 222; and Dr. Allen Thomson, in Cyclop. Anat. and Physiol., part. xiii. p. 469, for Feb. 1838.

[7] Thomas B. Taylor, New Orleans Journal of Medicine, Nov. 1848; and R. Carter, Medical Examiner, Sept. 1849, p. 523.

therefore, as regards the possibility of a second vesicle being fecundated, prior to the closure of the os uteri by the tenacious impenetrable mucus (*mucus infranchissable*, Pouchet), and the flocculent membranous secretion from the interior of the uterus, or by the decidua, no doubt, we think, can be entertained; but, except in cases of double uterus, it would seem to be impracticable afterwards; although cases have been adduced to show its possibility. Still, these may perhaps be explained under the supposition, that the uterine changes, above referred to, may not be as rapidly accomplished in some cases as in others; and, again, the period of gestation is not so rigidly fixed, but that children, begotten at the same time, or within a few days of each other, may still be born at a distance of some weeks. A case happened to the author in which nearly three weeks elapsed between the birth of twins, in whose cases the ova were probably fecundated either at the same copulation, or within a few hours of each other.

It may happen, too, that although two ova may be fecundated, both embryos may not undergo equal developement. One, indeed, may be arrested at an early stage, although still retaining the vital principle. In such a case, the other will generally be found larger than common. A case of the kind occurred in the practice of Professor Hall, of the University of Maryland, and many such are on record. On the 4th of October, 1835, a lady was delivered of a female fœtus, 2 inches and 10 lines in length. This occurred about half-past eight in the morning; and at two o'clock on the following morning, she was delivered of a second child, which weighed $9\frac{1}{2}$ pounds. The fœtus, whose developement was arrested, was seen by the author. When first extruded, it gave no evidences of decay, and in colour and general characters resembled the fœtus of an ordinary abortion.[1] Still, there are many cases recorded, in which the interval between the births of the children has been from 110 to 170 days, and neither of the children was in appearance premature; so that the possibility of a second conception, when the uterus already contains an ovum several months old, can scarcely, perhaps, be denied, however improbable it may seem; and, indeed, if the facts be admitted, the deduction seems to be irresistible.

f. *Pregnancy.*

When the fecundated ovum has been laid hold of by the fimbriated extremity of the Fallopian tube, and through this channel,—perhaps by the contraction of the tubes and the ciliary motions of its lining membrane,—has reached the cavity of the uterus, it forms a union with that viscus, to obtain the nutritive fluids which may be required for its developement, and to remain there during the whole period of *pregnancy* or *utero-gestation;*—a condition that will now require consideration.

Immediately after a fecundating copulation, and whilst the chief

[1] For similar cases, of which many are on record, see Dr. Samuel Jackson, formerly of Northumberland, Pa., now of Philadelphia, in American Journal of the Medical Sciences, May, 1838, p. 237, and May, 1839, p. 256; also, Dr. J. G. Porter, ibid., Aug. 1840, p. 307; Mr. Streeter, Lond. Lancet, Oct. 30, 1841: Dr. H. N. Loomis, Buffalo Medical Journal, June, 1845; and Dr. E. Horlbeck, Charleston Medical Journal and Review, Jan. 1848.

changes are transpiring in the ovary, certain modifications occur in the uterus. According to some, it dilates for the reception of the ovum. Bertrandi found this to be the case in extra-uterine pregnancy, and in females whom he opened at periods so near to conception, that the ovum was still floating in the uterus. Its substance appeared at the same time redder, softer, less compact, and more vascular than usual. In the case from Sir Everard Home,[1] to which allusion has been made more than once, the lining of the uterus was covered by a beautiful flocculent exudation about the seventh or eighth day after impregnation. The soft membrane, which forms in this way, is the *membrana caduca* seu *decidua externa*, first described by Hunter; the *epichorion* of Chaussier; *tunica exterior ovi*, *t. caduca*, *t. crassa membrana cribrosa*, *membrana ovi materna*, *membrana mucosa*, *decidua cellularis* et *spongiosa*, of others.

Fig. 397.

Decidua Uteri. (Von Baer.)

The dark shade, over and between the villi, is the decidua. The uterine vessels are seen extending into the decidua and forming loops there.

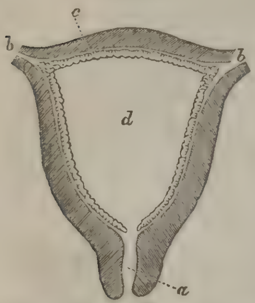
In a case, observed by Von Baer at a very early period, when the decidua was still in a pulpy state, the villi of the lining membrane of the uterus, which in the unimpregnated state are very short, were found to be remarkably elongated; and between the villi, and passing over them, was a substance not organized, but merely effused, and evidently the decidua at an extremely early age.[2] Others, as Weber[3] and Sharpey,[4]—and the view has been embraced by many eminent observers,—have maintained, that the decidua is composed of the mucous membrane itself, which has undergone a considerable change in its character, and in the secretion from its follicles.

The arrangement of this membrane has given rise to much discussion. The opinions of most of the anatomists of the present day are in favour of one of two views. It is maintained by some, that one of the first effects of conception is to cause the secretion of a quantity of a sero-albuminous substance from the inner surface of the uterus; so that the organ becomes filled with it. At first, when the ovum arrives in it, it falls into the midst of this secretion, gradually absorbing a part for its nutrition by its outer surface. The remainder is organized into a double membrane, one corresponding to the uterus, the other adhering to the ovum. This sero-albuminous substance has been assimilated both to the white with which the eggs of birds become invested in passing through the oviduct; and to the viscid substance that envelopes the membranous ova of certain reptiles. It is conceived, by some, to plug up both the orifices of the Fallopian tubes, and that of the uterus; and, according to Krummacher[5] and Dutrochet,[6] it has been seen extending into the tubes; whilst the remains of that which plugged up the os uteri has been recognised in the shape of a nipple on the top of

[1] Lect. on Comp. Anat., iii. 209, Lond., 1823.
[2] Op. citat.; and Wagner's Physiology, by Willis, p. 184, Lond., 1841.
[3] Hildebrandt, Handbuch der Anatomie, iv. 486 and 515, Braunschweig, 1832.
[4] Müller's Elements of Physiology, by Baly, note at p. 1574, Lond., 1838.
[5] Diss. Sistens Observationes quasd. Anatom. circa Velamenta Ovi humani, Duisb., 1790.
[6] Mém. de la Société Médicale d'Emulation, viii. p. i. 1817.

the aborted ovum. To this substance M. Breschet[1] has given the name *Hydropérione*. By others, it has been held, that a decidua is formed prior to the arrival of the ovum, lines the whole of the cavity and is devoid of apertures; so that when the ovum passes along the tube and attains the cornu of the uterus, it pushes the decidua before it;—the part so pushed forwards constituting the *tunica decidua reflexa* or *ovuline*, and enveloping the whole of the ovum except at the part where the decidua leaves the uterus to be reflected over it. This is the seat of the future *placenta.* Such is the view of MM. Velpeau,[2] Wagner,[3] Kirkes and Paget[4] and others. An objection to it, however, is the difficulty of so small a body pushing the decidua before it; and a still stronger is the assertion of Professor Sharpey, that the structure of the decidua and of the decidua reflexa is different, a fact long since mentioned by Dr. William Hunter,[5] who describes the decidua reflexa as a membrane of considerable thickness, and of a yellower colour than the decidua vera.[6] Hence, it has been thought more probable, that the latter is almost entirely a new production, the growth of which is simultaneous with the enlargement of the ovum; and that the decidua vera has no more share in its formation than by supplying, through its vessels, the necessary materials. At the point of supposed reflection of the decidua reflexa, there is a thick stratum of a substance precisely similar to the decidua reflexa, which attaches the ovum to the side of the uterus, and blends intimately on the outer side of the reflex fold with the decidua vera. This is termed *decidua serotina*, from its appearing to have been formed at a later period. It is represented in Fig. 400.

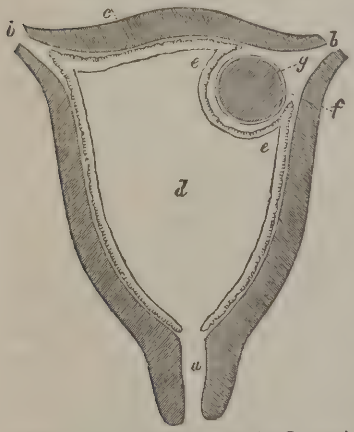
Fig. 398.



Section of the Uterus about eight days after Impregnation. (Wagner.)

a. Cervix. *b, b.* Orifices of Fallopian tubes. *c.* Decidua vera. *d.* Cavity of uterus.

Fig. 399.



Section of the Uterus when the Ovum is entering its Cavity. (Wagner.)

Ovum, *f*, surrounded by its chorion *g*. *a.* Cervix. *b, b.* Fallopian tubes. *c.* Decidua vera. *d.* Cavity of the uterus. *e.* Decidua reflexa.

[1] Etudes Anatomiques, Physiologiques, et Pathologiques de l'Œuf dans l'Espèce Humaine, &c., Paris, 1832.

[2] Traité Elémentaire de l'Art des Accouchemens, i. 231, Paris, 1829, or Prof. Meigs's translation, 2d edit., p. 246, Philadelphia, 1838; also, Embryologie ou Ovologie Humaine, Paris, 1833.

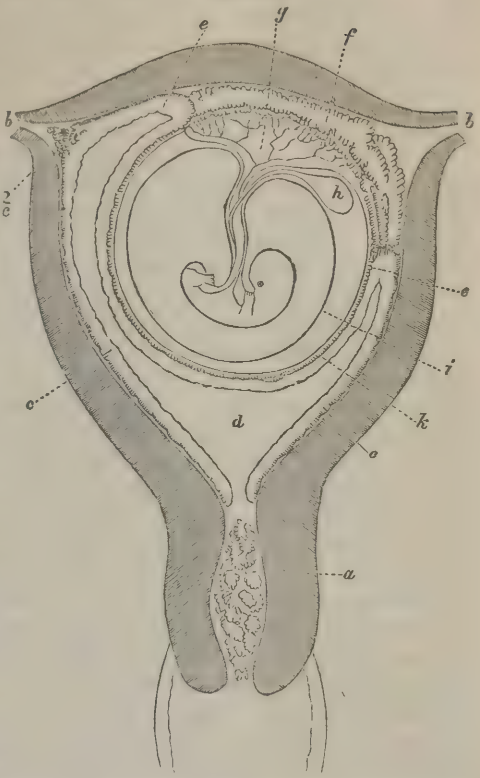
[3] Op. citat., p. 188.

[4] Manual of Physiology, Amer. edit., p. 481, Philad., 1849: see, on this subject, Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation, and Developement, p. 90, Lond., 1848.

[5] Anatomical Description of the Gravid Uterus and its Contents, Lond., 1799.

[6] Müller, loc. cit.

Fig. 400.



Section of the Uterus with the Ovum somewhat advanced. (Wagner.)

a. Muco-gelatinous substance, blocking up os uteri. *b*, *b*. Fallopian tubes. *c*, *c*. Decidua vera prolonged, at *c* 2, into Fallopian tube. *d*. Cavity of uterus, almost completely occupied by ovum (compare with Fig. 399). *e*, *e*. Angles at which decidua vera is reflected. *f*. Decidua serotina. *g*. Allantois. *h*. Umbilical vesicle. *i*. Amnion. *k*. Chorion, lined with outer fold of serous tunic.

The view of Dr. Burns[1] differs from this in supposing that the decidua consists of two layers, the innermost of which has no aperture, so that the ovum on attaining the cornu of the uterus pushes it forwards, and it forms the *decidua protrusa* or *decidua reflexa;* and a somewhat modified view of the same kind appears to be entertained by Prof. Weber. Impregnation, according to M. Velpeau, occasions a specific excitation in the uterus, promptly followed by an exhalation of coagulable matter. This concretes, and is soon transformed into a kind of cyst or ampulla, filled with a transparent or slightly rose-coloured fluid. This species of cyst is in contact with the whole surface of the uterine cavity, and sometimes extends into the commencement of the tubes, and most frequently into the upper part of the cervix uteri, in the form of solid concrete cords; but is never, he says, perforated naturally, as Hunter, Bojanus, Lee, and others have maintained. The decidua uteri, according to M. Velpeau, retains a pretty considerable thickness, especially around the placenta, until the end of gestation: the decidua reflexa, on the contrary, becomes insensibly thinner and thinner, so that at the full period it is at times of extreme tenuity. Towards the third or fourth month—a little sooner or later—they touch and press upon each other, and remain in a more or less perfect state of contiguity, until the expulsion of the secundines; but M. Velpeau asserts they are never confounded; and such appears to be the view of Bischoff.[2] The decidua—the true as well as the reflected—is esteemed by M. Velpeau a simple concretion—a layer without regular texture—the product of an excretion from the lining membrane of the uterus; on

[1] Principles of Midwifery, 3d edit., p. 147, Lond., 1814.
[2] Wagner, op. citat., p. 190 (note).

this account, he terms it, "*anhistous membrane*," (from αν, privative, and ἱστος, "a web") or "membrane without texture." There has, indeed, been a striking dissatisfaction with the name "decidua." Besides the appellatives already given, M. Dutrochet has proposed to call it *épione*, M. Breschet, *périone*, Seiler, *membrana uteri interna evoluta*, and Burdach, *nidamentum*.

A difficulty exists in understanding how the decidua is formed continuously over the orifice of the Fallopian tubes, and the upper surface of the cervix uteri. A new production must evidently take place there. By some, however, it is not presumed to exist in the latter situation; but a plug of muco-gelatinous matter is found there, as in Fig. 400, *a*.

The use of the decidua is, in M. Velpeau's opinion, to retain the fecundated ovum to a given point of the uterine cavity; and if his views of its arrangement were correct, the suggestion would be good. In favour of it a good deal might be said. If there were apertures in the decidua corresponding to the Fallopian tubes, it would seem, that the ovum ought more frequently to fall into the sero-albuminous matter, about the cervix uteri, and attachment of the placenta over the os uteri ought, perhaps, to occur more frequently than it is known to do. When placenta prævia does exist, it is owing, in the opinion of Dr. Doherty,[1] to the decidua being imperfect, or to the ovum descending into the uterine cavity before that membrane has acquired sufficient consistence and tenacity to resist its weight: the consequence is, that the ovum must make its way to the cervix uteri and give occasion to implantation of the placenta there. Under M. Velpeau's doctrine, the attachment of the placenta ought generally to be near the cornu of the uterus, which is, in fact, the case. Of 34 females, who died in a state of pregnancy at the *Hôpital de Perfectionnement*, an examination of the parts exhibited, that in twenty the centre of the placenta corresponded to the orifice of the Fallopian tube; in three, it was anterior to it; in two, posterior; in three, beneath; and in six, near the fundus of the uterus. It is not so easy to subscribe to his assertions regarding the "anorganic" nature of the decidua. Many excellent observers have affirmed, not only that this membrane exists between the placenta and the uterus, which M. Velpeau's view, of course, renders impossible, but that numerous vessels pass between it, the uterus, and the placenta. We know, too, that the safest and most effectual mode of inducing premature labour is to detach the decidua from the cervix uteri, or, in other words, to break up the vessels that form the medium of communication between it and the lining membrane of the uterus. It may be said, indeed, that the mere separation of the "anorganic pellicle"—as M. Velpeau designates it—is a source of irritation, and may excite the uterus to the expulsion of its contents, and this is possible; but he affirms, that no tissue attaches the decidua to the uterus; and that it adheres to the inner surface of the organ merely in the manner of an excreted membraniform shell (*plaque*). The views of MM. Lepelletier[2] and M. Raspail[3] coincide with those of M. Vel-

[1] The Dublin Journal of Medical Science, July, 1845, p. 333.
[2] Physiologie Médicale et Philosophique, iv. 339, Paris, 1833.
[3] Chimie Organique, p. 270, Paris, 1833.

peau as to the decidua being an excretion; but those of M. Raspail are modified by his peculiar opinions. He maintains, that the surfaces of an organ—whether external or internal—having once fulfilled their appropriate functions, become detached and give place to the layer beneath them; and we have before remarked, that he considers the secretions of the mucous and serous membranes to be constituted of the *detritus* of those membranes. Now, that which happens to the intestinal canal and bladder must likewise happen, he affirms, to the uterus; and as, at the period of gestation, it surpasses in developement, elaboration, and vitality, every other living organ, it ought necessarily to cast off its layers, in proportion as they have executed the work of elaboration. These *deciduous* layers constitute the *decidua*, on which, he says, traces of a former adhesion to the parietes of the uterus, and of the three apertures into the organ, may be met with.

But the very existence of a decidua reflexa has been denied. It is so by Jörg,[1] Samuel,[2] and by Dr. Granville, who affirms, that it is now scarcely admitted by one in ten of the anatomists of the European continent. He refers to a specimen of an impregnated uterus in the Museum of the Royal College of Surgeons of London, which has distinctly a round ovum, suspended naturally within the decidua, as a globe may be supposed to hang from some point of the interior of an oblong sac; and to two specimens, in the collection of Sir Charles Clarke, exhibiting an ovum, which had already penetrated about an inch into the cavity of the uterine decidua; but neither in these, nor in the specimen at the Royal College, is any part of the uterine decidua pushed forward. The ovum appears to have its natural covering; and, in the College specimen, there is a large space between it and the deciduous lining of the uterus. Dr. Granville regards the decidua reflexa as the external membrane of the ovum, to which Professor Boër, of Königsberg, gave the name "cortical membrane," and which he terms *cortex ovi*.[3] It has received various names. By Albinus, it was termed *involucrum membranaceum;* by Hoboken, *membrana retiformis chorii;* by Roederer, *membrana filamentosa;* by Blumenbach, *membrana adventitia;* and by Osiander, *membrana crassa.* To this membrane—and to the decidua uteri, as connected with the placenta—we shall have to refer hereafter.

The decidua manifestly does not belong to the ovum; for it not only exists prior to the descent of the ovum into the uterus, but is even formed, according to M. Breschet,[4] in all cases of extra-uterine pregnancy. (See Fig. 401.) Chaussier saw it in several cases of tubal gestation. It was present in a case of abdominal pregnancy, cited by Lallemant; and, according to M. Adelon,[5] Evrat affirms, that one is secreted after every time of sexual intercourse,—which is apocryphal! It would appear, however, to be formed at each menstrual period, and,

[1] Das Gebärorgan des Menschen, u. s. w., Leipz., 1808.
[2] De Ovorum Mammal. Velament. Wirceb., 1816; and art. Ei, in Encyclop. Wörterb. der Med. Wissensch., x. 107, Berlin, 1834.
[3] Graphic Illustrations of Abortion, &c., p. v., Lond., 1834.
[4] Repert. Général d'Anatomie, p. 165, pour 1828.
[5] Physiologie de l'Homme, 2de édit., iv. 110, Paris, 1829.

according to M. Pouchet,[1] is thrown off from the tenth to the fifteenth day afterwards. He is of opinion, that the decidua is produced simply by the irritation, which succeeds to menstruation, and that it is nothing more than a pseudo-membrane "secreted between the surface of the mucous membrane and the epithelium," and taking the latter with it, is afterwards discharged;—an arrangement which is not very intelligible. Dr. Robert Lee[2] affirms, that it is not formed within the uterus in all cases of extra-uterine gestation; and in ten cases detailed by him, and in one cited from M. Chaussier, it was seen distinctly surrounding the ovum in the Fallopian tube.[?]

Fig. 401.

Extra-Uterine Pregnancy.

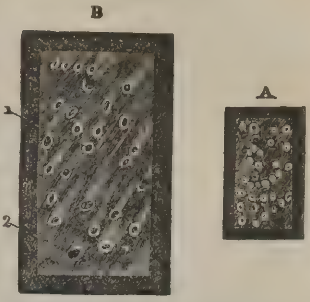
a. Uterus, its cavities laid open. *b*. Its parietes thickened, as in natural pregnancy. *c*. A portion of decidua separated from its inner surface. *d*. Bristles to show the direction of the Fallopian tubes. *e* Right Fallopian tube distended into a sac which has burst, containing the extra-uterine ovum. *f*. Fœtus. *g*. Chorion. *h*. Ovaries; in the right one is a well-marked corpus luteum, *i*.

The views of Professor Goodsir[3] on the morphology of the decidua merit great attention. By the observations of Weber and Sharpey, it had been shown, that it is not a structure of new formation; but that when impregnation has taken place, the mucous membrane of the uterus swells and becomes lax, its tubular follicles—*glandulæ utriculares*—increase in size, secrete a granular matter, and are lined with epithelium; and its capillaries enlarge proportionally. M. Coste[4] restricts the uterine changes to these. "The only modifications"—he remarks—"of which the uterus becomes the seat consist in the turgescence or erethism of its tissue, and more especially in a considerable thickening of the mucous membrane:—a thickening which results especially

[1] Théorie Positive de l'Ovulation Spontanée, p. 254 and p. 463, Paris, 1847.
[2] Lond. Med. Gazette, June 5, 1840.
[3] Anatomical and Pathological Observations, Edinb., 1845.
[4] Histoire générale et particulière du Développement des Corps Organisés, p. 220, Paris, 1847.

from congestion of the bloodvessels, and an extreme developement of the glands, that enter into its composition, and, in certain subjects, plait them into more or less numerous convolutions." "In the normal state"—he affirms—"neither the opening of the cervix uteri nor that of the Fallopian tubes is closed by membrane." They are always free, permeable, and consequently permit the ovum to pass into the cavity of the uterus, and the folds of the mucous membrane, by coming in contact, are sufficient to arrest it. Mr. Goodsir has remarked, however, that the interfollicular spaces, in which the network of capillaries lies, are occupied by a texture consisting entirely of nucleated particles; "this is a tissue represented by Baer and Wagner, and described by them as surrounding what they supposed to be uterine papillæ (really the enlarged follicles), and considered by them as decidua." The increased thickness of the mucous membrane appears as much due to the develope-

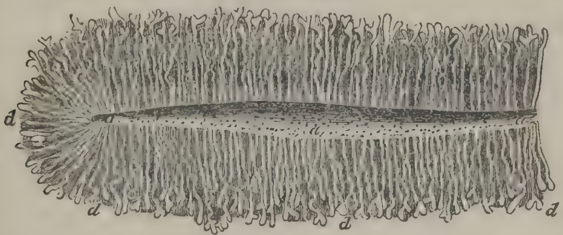
Fig. 402.



Two thin segments of Human Decidua, after recent impregnation, viewed on a dark ground; they show the openings on the surface of the membrane.

A is magnified six diameters and B twelve diameters. At 1, the lining of epithelium is seen within the orifices; at 2 it has escaped. (FromDr. Sharpey.)

Fig. 403.



Section of the lining membrane of a human uterus at the period of commencing pregnancy, showing the arrangement and other peculiarities of the glands *d*, *d*, *d*, with their orifices, *a*, *a*, *a*, on the internal surface of the organ. Twice the natural size. (After E. H. Weber.)

ment of this interfollicular substance, as to the enlargement of the follicles. About the time at which the ovum reaches the uterus, the developed mucous membrane or decidua begins to secrete; the os uteri becomes plugged up by the secretion, which there assumes the form of elongated epithelial cells; the cavity of the uterus becomes filled with a fluid secretion, the *hydropérione* of M. Breschet; and in the immediate neighbourhood of the ovum, it consists of cells of a spherical form. Thus, the decidua, according to him, consists of two distinct elements; —the mucous membrane of the uterus thickened—as remarked by Dr. Sharpey, and confirmed by Bischoff,[1] Courtz,[2] and others—by a peculiar developement, and by non-vascular cellular substance, the product of the

[1] Müller's Archiv., H. ii., 1846, p. 111.
[2] Archives d'Anat. général et de Physiol., Sept. 1846; cited by Dr. Kirkes in Ranking's Abstract, vol. iv.

uterine follicles; the former constitutes, at a later period, the greater part of the decidua vera; the latter the decidua reflexa. This view of the constitution of the decidua—in Mr. Goodsir's opinion—clears up the doubts which were entertained regarding the arrangement of these membranes at the os uteri and the entrances of the Fallopian tubes. The orifices will be opened or closed, according as the cellular secretion is more or less plentiful, "or in a state of more or less vigorous developement." It removes also—he conceives—the difficulty of explaining how the decidua covers the ovum—a difficulty, which cannot be reconciled with the views of Dr. Sharpey, who supposes a deposition of lymph—the old view of the constitution of the decidua. When the ovum enters the cavity of the uterus, the cellular decidua surrounds it, and becomes the decidua reflexa by a continuance of the same action by which it had been increasing in quantity prior to the arrival of the ovum. The cellular decidua grows around the ovum, by the formation of new cells, the product of those in whose vicinity the ovum happens to be situate. At this stage of its growth, the ovum with its external membrane, the chorion, which is covered by the tufts whose structure and functions are described elsewhere, is embedded in a substance that consists wholly of active nucleated cells. The absorbing cells of the tufts are constantly taking up either the matter resulting from the solution of the cells of the cellular decidua, or the fluid contained in those cells,—in either case from matter supplied by the vessels of the uterus, but selected and prepared by the cells of its lining membrane, now become the decidua.[1]

Mr. Goodsir's view harmonizes more than any other with the mode in which new structures would seem to be formed elsewhere, but farther observations are needed before this interesting and intricate topic of histology can be considered settled.

When the ovum attains the interior of the uterus, which it probably does within the first ten or twelve days after conception, it forms, in a short space of time, a connexion with the uterus by means of the placenta, in the mode to be mentioned hereafter. During the developement of the embryo, it is requisite that the uterus should be correspondently enlarged, in order to afford room for it, as well as to supply it with its proper nutriment. These changes in the uterine system will engage us exclusively at present. In the first two months, the augmentation in size is not great, and chiefly occurs in the pelvis; but, in the fourth, the increase is more rapid. The uterus is too large to be contained in the pelvis, and consequently rises into the hypogastrium. During the next four months, it increases, in every direction, occupying a larger and larger space in the cavity of the abdomen, and crowding the viscera into the flanks and the iliac regions. At the termination of the eighth month, it almost fills the hypogastric and umbilical regions; and its fundus approaches the epigastric region. After this, the fundus is depressed and approaches the umbilicus, leaving a flatness above, which has given rise to the old French proverb :—*En ventre plat enfant y a.* During the first five months of utero-gestation, the womb

[1] British and Foreign Med. Rev., Oct. 1845, p. 303.

experiences but little change, maintaining a conoidal shape. After this, however, the neck diminishes in length, and is ultimately almost entirely effaced. The organ has now a decidedly ovoid shape; and its bulk, according to Haller and Levret, is eleven and a half times greater than in the unimpregnated state. Its length, at the full period, has been estimated at about a foot; its transverse diameter at nine inches: its circumference on a level with the Fallopian tubes, at twenty-six inches; and, at the uterine portion of the cervix uteri, thirteen inches. Its weight, which, prior to impregnation, was from fourteen to eighteen drachms, is, at this time, from a pound and a half to two pounds.

Whilst the uterus is undergoing expansion, the size and situation of the parts attached to it also experience modification. The broad ligaments are unfolded; the ovaries and Fallopian tubes are raised a little, but are subsequently applied against the sides of the uterus. The vagina is elongated. The round ligaments yield to the elevation of the organ as far as their length will permit; but, ultimately, they draw the uterus forward, so that the great vessels of the abdomen are not injuriously compressed. The parietes of the abdomen are so much distended that the cuticle yields; hence, an appearance of cicatrices always exists on the abdomen of one who has borne children; and occasionally, the fasciculi of the abdominal muscles separate so as to give rise to ventral hernia.

The changes, produced in the uterus, are not limited to simple dilatation of its tissue. Its condition experiences various alterations, dependent upon the new mode of nutrition it has assumed. The whole organ undergoes not only extension but inspissation of its parietes. In its unimpregnated state, it is about four lines thick; in the third month of utero-gestation, five. Its arteries, as well as veins, enlarge, and the latter form large dilatations at the inner surface. These have been called *uterine sinuses*. Its lymphatics are greatly increased in size; and its proper tissue, from being hard, whitish, and incontractile, becomes red, soft, spongy, and capable of energetic contraction. It has been the general opinion, that the nerves exhibit a corresponding increase during the gravid state, but the dissections of Mr. Beck,[1] which have received favour from Dr. Sharpey,[2] prove, that they do not alter in their thickness, "at least, that no alteration occurs before they enter the tissue of the uterus." The representations of the gravid uterus, and of the unimpregnated uterus of one who had borne children, which are given in Mr. Beck's communication, show the nervous fibrils to be the same in both cases; and no difference was observed on the dissection of a virgin uterus between its nerves and those referred to. M. Jobert,[3] too, observed no difference in the nerves in the impregnated and the unimpregnated state; and M. Rendu[4] considers, that the knots observable in the course of the nerves during pregnancy are not formed of

[1] Philosophical Transactions, Part 2 for 1846.

[2] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit., by Leidy, ii. 356, Philad., 1849.

[3] Comptes Rendus, Paris, 1841.

[4] Thèse de Paris, 1842; cited by Ollivier, Art. Utérus (Anatomie) in Dict. de Médecine, xxx. 194, Paris, 1846.

nervous substance, but of the fibro-cellular tissue that sustains and protects them.

A difference of sentiment has existed with regard to the nature of the new tissue of the uterus; some comparing it to the middle coat of arteries; others describing it as partly areolar and partly muscular; but an immense majority esteeming it muscular. The respectable name of Blumenbach[1] is in the minority. The facts in favour of its muscularity are, indeed, overwhelming. It is clearly muscular in the mammiferous animal. Thus, in the rabbit, its muscularity, according to Dr. Blundell,[2] is far more conspicuous than that of the intestines; the fibres can be seen coarse and large, and their motion may be observed, if they be examined immediately after the rabbit is killed. The same acute physiologist remarks, that, when developed by pregnancy, its muscularity is so clear, that if you take a portion of it, and show it to any anatomist, asking him what its nature is, he will unhesitatingly reply—it is muscular. This experiment, he says, he once made himself. He took a piece of the impregnated uterus, showed it to Mr. Green and Mr. Key—"excellent judges on this point,"—and, without mentioning the womb, asked them to tell him what was the structure; when they immediately declared it muscular. A similar experiment had previously been tried upon Mr. Else, who had made up his mind as to the non-muscularity of the organ. A small portion was taken to him for his opinion of its precise nature. It was from the uterus at an advanced period of utero-gestation. After carefully examining it, he gave for answer, that in his opinion it was muscular; but as it was detached from its natural locality, he could not say to what part of the body it belonged. When told, however, that it was a piece of the uterus, he examined it again, and *then* said that it could not be muscle, for there were no muscular fibres in the uterus.[3] The arrangement of the fibres is not clearly demonstrated. Generally, perhaps, they are described as running externally, in a longitudinal direction, from the fundus to the neck: beneath this plane is another with circular fibres; but within this the fibres are interlaced in inextricable confusion. Some anatomists, however, enumerate as many as seven superposed planes. The fibres are of much lighter colour than those of ordinary muscles; resemble more those of the bladder and intestines, and are collected in very flat and loose fasciculi. Under the microscope, they are manifestly of the nonstriated kind; but, towards the end of utero-gestation, fibres, of a faintly striated character, resembling those of the heart—it is affirmed—have been seen. The developement of this structure would not seem to be limited to the pregnant condition. It appears to occur whenever the uterus is increased in size, as has been remarked by Dr. Horner[4] and by Lobstein.[5] The muscular layers are thickest at the fundus uteri. At the cervix, they are extremely small and indistinct.

After the ovum has attained the interior of the uterus, and entered

[1] Instit. Physiol., § 547.

[2] Principles and Practice of Obstetricy, Amer. edit., p. 67, Washington, 1834.

[3] D. Davis, Principles and Practice of Obstetric Medicine, ii. 850, Lond., 1836.

[4] Lessons in Practical Anatomy, p. 304, Philad., 1836.

[5] Fragment d'Anatomie Physiologique sur l'Organisation de la Matrice dans l'Espèce Humaine, Paris, 1803.

the flocculent decidua, it becomes connected, in process of time, with the uterus, by means of a body to be described hereafter called *placenta*, which is attached to the uterus, and communicates with the fœtus by a vascular cord that enters its umbilicus. The seat of the attachment of the placenta to the uterus—we have seen—is not always the same. Frequently, it is near one of the cornua; but occasionally is implanted over the os uteri. The diversity of position has given occasion to difference of sentiment regarding the causes that influence it. By some, it has been presumed, that, in whatever part of the uterus the ovum lodges when it quits the Fallopian tube, there an adhesion is formed. By others, it has been said, that as the ovum pushes the decidua over the mouth of the Fallopian tube before it, the attachment of the placenta must be near the orifice of the tube. Such would appear to be the fact in the majority of cases, but we see so many irregularities in this respect, as to preclude us from assigning any very satisfactory reason for it.

g. *Signs of Pregnancy.*

Along with the changes that supervene in the generative apparatus during pregnancy, the whole system commonly sympathizes more or less in the altered condition. Some females, however, pass through the whole course of gestation with but slight or no disturbance of the ordinary functions; whilst with others, it is a period of incessant suffering. One of the earliest and most common signs is suppression of the catamenial discharge; but, of itself, this cannot be relied on, as it may result from disease. Soon after impregnation, the digestive and cerebral functions exhibit more or less modification. The female is affected with nausea and vomiting, especially in the morning after rising; the appetite is most fastidious—substances, that previously excited loathing being at times desired or *longed* for with the greatest avidity; whilst, on the contrary, cherished articles of diet cannot be regarded without disgust. The sleep is apt to be disturbed; the temper unusually irritable, even in those possessed of signal equanimity on other occasions. The mammæ enlarge, and become knotty, and sometimes lancinating pains are felt in them; and a secretion of a whitish serum can often be pressed out. The areola round the nipple becomes of a darker colour in the first pregnancy than it is in the virgin state; and it is darker during each successive pregnancy, than when the female is not pregnant. There is, also, a puffy turgescence, not alone of the nipple, but of the whole of the surrounding disk, with a developement of the small follicles around the nipple. These appearances constitute one of the best single proofs of the existence of pregnancy; but it is obvious, that for accurate discrimination, it is necessary to be aware of the hue in each particular case in the unfecundated state; and, moreover, instances are on record of a well-marked areola occurring in persons who are not pregnant, as well as of an entire absence of areola in those who are. Dr. Guy remarks, that Dr. J. Reid showed him a case of enlarged mammæ, with distinct areolæ and mucous follicles, in a female who had never been, and was not at the time, pregnant.[1]

[1] Lond. Lancet, Dec. 22, 1838.

Dr. Simpson[1] presented before the Edinburgh Obstetrical Society a woman, seven months gone with child, whose breasts gave no indication whatever of her pregnant state. There was no appearance on either of enlarged follicles, and the areola was scarcely darker than the surrounding skin; yet that she was pregnant was shown by the fact, that the pulsations of the fœtal heart were distinctly heard. Dr. Simpson contrasted this case with that of a lady, who had never been pregnant, but who was suffering from great uterine irritation. In her, the areola was turgid, and of a dark brown colour; and the papillæ were numerous and much enlarged.

The author has had numerous opportunities for appreciating the insufficiency of these evidences taken singly.

It has been affirmed by Dr. Kluge, of Berlin, M. Jacquemin, of Paris, and Dr. D'Outrepont,[2] that a bluish tint of the vagina, extending from the os externum to the os uteri, is a sure test of pregnancy. According to Kluge, this discoloration commences in the fourth week of utero-gestation, increases until the time of delivery, and ceases with the lochia. M. Jacquemin, on examining the genitals of prostitutes, in compliance with the police regulations of Paris, observed the same peculiarity of colour in the same situation in those that were pregnant: he describes it as a violet or lees of wine colour, and so distinct as never to deceive him, being sufficient of itself, and independently of other signs of pregnancy, to determine the existence of that state. M. Parent-Duchatelet[3] affirms, that he was present when M. Jacquemin's accuracy in this matter was successfully put to the test: in the investigation, he examined no less than 4500 prostitutes. Dr. D'Outrepont has not only met with this appearance uniformly in the human subject, but in different animals, examined in every period of pregnancy, and which he destroyed, to ascertain the existence or non-existence of gestation; and similar testimony has been given recently by Dr. Albert.[4] Dr. Montgomery,[5] however,—from limited observation it is true,—found, that whilst in some cases the bluish colour was very obvious, in others it was so slight as to be scarcely, or not at all, perceptible.

There is nothing more probable, than that the capillary circulation of the mucous coat of the vagina may be modified along with that of the interior of the uterus during pregnancy, so as to give occasion to the change of colour mentioned by those eminent observers; but it may be doubted whether the test can often be available, especially in private practice.

It is the general opinion, that the blood of pregnancy always presents the buffy coat and other characters of inflammation; and this has even been reckoned as one of the rational signs of pregnancy. Dr. Montgomery[6] ascribes the very general belief in this as an established

[1] Monthly Journal of Medical Science, July, 1848, p. 244.

[2] Zeitschrift für Geburtsk. xiv. 3; cited in Philad. Medical Examiner, Feb. 24, 1844, p. 46.

[3] De la Prostitution dans la Ville de Paris, i. 217, 218, Paris, 1837.

[4] Zeitschrift für Geburtskunde, xxiii. 449, cited in British and Foreign Medico-Chirurgical Review, July, 1848, p. 267.

[5] Op. citat., p. vi., Lond., 1837.

[6] Art. Pregnancy and Delivery, Signs of, in Cyclop. of Pract. Med., Amer. edit., by the author, iii. 679, Philad., 1845.

fact to the circumstance, that pregnant women are seldom bled except when labouring under some form of inflammatory disease; and he affirms, that he has often found the blood of the pregnant female without these characters. Hematological researches, however, show that the blood in pregnancy is materially altered. Simon[1] found that of a woman in the fifth month with a slight buffy coat, but in other respects it did not differ physically from normal blood; and MM. Becquerel and Rodier[2] analyzed that of nine pregnant women,—one at the fourth month, five at the fifth month, one at five months and a half, one at six months, and one at seven months. From these they concluded, that although pregnancy, when not far advanced, and when it has not yet exerted any sensible influence on the constitution, may not occasion any obvious alteration of the blood, it becomes sensibly changed as pregnancy advances;—the main modifications being—that the density both of the defibrinated blood and the serum is diminished; the water, fibrin, and phosphorized fat are increased; whilst the corpuscles and albumen are diminished. For these and other reasons, it has been maintained by M. Cazeaux[3] that the cause of many of the functional derangements in pregnancy, which are attributed to polyæmia or plethora, is really owing to hydræmia or a condition of the blood like that of chlorosis.

Some years ago,[4] it was affirmed, that a German physician, Dr. Pallender, during a practice of eighteen years, had observed a peculiar smell of the vaginal mucus to be a constant and unerring sign of pregnancy. The smell is musty, something resembling that of sperm or of liquor amnii; and after a vaginal examination, he says, cannot be mistaken for any other odour. In a great many cases of pregnancy, in the first, second, and third months, when the condition of the patient was doubtful owing to the early period, he never, in a single instance, failed to discover the true state of the case by means of this sign. According to his latest observations, the odour is perceptible as early as the eighth day of utero-gestation. The author knows nothing of this sign.

Attention has been paid to the condition of the urine during utero-gestation; but although a difference has appeared to exist between it and that of an unimpregnated female, it has not generally been esteemed distinctive. M. Donné,[5] indeed, affirms, that in pregnancy it contains less uric acid and phosphate of lime than in the natural state, —a difference explicable if we consider the elements that are necessary for the formation of the organs of the fœtus. The crystallization of the salts of the urine is so remarkably modified, that by simple inspection, without examining the female, he recognised in more than thirty cases the state of pregnancy at different periods. The observations of M. Donné in regard to the diminution in the quantity of earthy phosphates in the urine are confirmed by Lehmann and Lubansky. It is a

[1] Animal Chemistry, Syd. Soc. edit., p. 335, Lond., 1845.
[2] Gazette Médicale de Paris, Nov. 23 and 30; and Dec. 7, 14, and 21, 1844.
[3] Archives Générales de Médecine, Mars, 1850, p. 356.
[4] Northern Journ. of Med., Nov. 1845; cited from Med. Corresp. Rhein und Westfal Aerzte, 1845, Bd. iv. H. i.
[5] Gazette Médicale de Paris, 29 Mai, 1841.

curious circumstance, connected with this matter, that Rokitansky[1] noticed a deposition of bony matter—*osteophyte*—on the inner surface of the parietes of the skull of pregnant women, who had died suddenly after the third month of utero-gestation; as well of those who had died of different diseases, sooner or later after delivery; this he had witnessed so frequently, that he considered there was a connexion between the deposition and the pregnant state. It does not appear, however, that the phenomenon has been observed in other countries. According to Rokitansky, the bony layer is generally deposited on the inner surface of the frontal and parietal bones; but, at times, it spreads over the whole of the inner surface of the cranium; and islets (*insulæ*) of it are observed on the base of the cranium.

Of late years, the urine of the pregnant female has been found to contain a peculiar substance, which separates and forms a pellicle on the surface. To observe this, it must be allowed to stand from two to six days, when minute opaque bodies are observed to rise to the surface, where they gradually agglomerate and form a continuous layer which is so consistent that it may be almost lifted off by raising it by one of its edges. To this pellicle the name *kiestein* or more properly *kyestein*, (from κυειν, "to be pregnant," and εσθης, "a pellicle,") has been given. It is whitish; opalescent; slightly granular, and may be compared to the fatty substance that swims on the surface of soups, after they have been allowed to cool. When examined by the microscope, it has the aspect of an amorphous mass, consisting of minute opaque corpuscles intermingled with crystals of ammoniaco-magnesian phosphate. The kyestein remains on the surface for several days; the urine then becomes turbid, and small opaque masses are detached from the kyestein and fall to the bottom of the fluid; the pellicle then soon becomes destroyed. The author has distinctly noticed in some of the cases the cheesy odour of kyesteinic urine described by Dr. Bird.

M. Simon[2] found the whole field of vision bestrewed with numerous vibriones in active motion, and crystals of ammoniaco-magnesian phosphate. M. Zimmerman,[3] too, states, that kyestein consists almost entirely of vibriones. These animalcules, he says, are first formed in the lower strata of the urine, which they render turbid. They then rise, in quantities, to the surface, where they form,—with crystals of ammonio-phosphate of magnesia, amorphous phosphate of lime and urate of ammonia,—the yellowish white pellicle—the kyestein.

Various experiments have been made on this matter, and its value as an index of the pregnant condition, by MM. Nauche,[4] Eguisier,[5] Dr. Golding Bird,[6] Mr. Letheby,[7] Dr. Stark,[8] the author's friend Dr. E. K.

[1] Pathologische Anatomie, ii. 237; cited by Litzmann, art. Schwangerschaft, Wagner's Handwörterbuch der Physiologie, 13te Lieferung, s. 76, Braunschweig, 1846.

[2] Animal Chemistry, Sydenham Society edition, ii. 331, Lond., 1846, or Amer. edit., Philad., 1846.

[3] Cited from Casper's Wochenschrift, May 30 and June 6, 1846, in Lond. Med. Gaz., Sept. 1846.

[4] La Lancette Française, and Lond. Lancet, No. clxvii. p. 675.

[5] La Lancette Française, Février 21, 1839; also, L'Expérience, Juillet 25, 1839.

[6] Guy's Hospital Reports, April, 1840.

[7] London Medical Gazette, Dec. 24, 1841.

[8] Edinb. Med. and Surg. Journal, Jan. 1842.

Kane,[1] of the United States Navy; and, at the author's request, by Drs. McPheeters and Perry,[2] at the time resident physicians at the Philadelphia Hospital, and by M. Kleybolte.[3] They show, that when taken in conjunction with other phenomena, the appearance of kyestein is certainly a valuable aid in the diagnosis of pregnancy. Mr. Letheby found unquestionable evidence of it in 48 out of 50 cases between the 2d and 9th month, and was unable to account for its absence in the two exceptional cases. The result of Dr. Kane's observations, which the author had an opportunity of examining from time to time, and for the accuracy of which he can vouch, was deduced by Dr. Kane as follows. *First.* Kyestein is not peculiar to pregnancy, but may occur whenever the lacteal elements are secreted without a free discharge from the mammæ. *Secondly.* Although it is sometimes obscurely developed and occasionally simulated by other pellicles, it is generally distinguishable from all others. *Thirdly.* Where pregnancy is possible, the exhibition of a clearly defined kyesteinic pellicle is one of the least equivocal proofs of that condition; and *Fourthly.* When the pellicle is not found in the more advanced stages of supposed pregnancy, the probabilities, if the female be otherwise healthy, are as 20 to 1 (81 to 4) that the prognosis is incorrect.

M. Simon,[4] who has made many observations on the subject, goes farther than Dr. Kane. "From the observations of Kane and myself," he remarks, "it seems to follow, that pregnancy may exist without the occurrence of kyestein in the urine. If, however, there is a probability or possibility of pregnancy, and kyestein is found, then the probability is reduced almost to a certainty."

By ether, Dr. Lehmann[5] succeeded in extracting from kyestein no inconsiderable quantity of a semi-solid fat, which, when saponified by potassa, and decomposed by sulphuric acid, emitted a decided odour of butyric acid. The residue of the film, which was insoluble in ether, showed on examination, that it was a protein compound differing in its properties from albumen. Dr. Lehmann concludes, that kyestein is no new peculiar substance; it is nothing more than a mixture of butyraceous fat, phosphate of magnesia, and a protein compound resembling casein.

Along with the signs already mentioned, the uterus gradually enlarges; and, about the end of the eighteenth week, sooner or later, *quickening*, as it is usually but erroneously termed, takes place, or the motion of the child is first felt. Prior to this,—from the moment, indeed, of a fecundating copulation,—the female is *quick* with child, but it is not until then, that the fœtus has undergone the developement necessary for its movements to be perceptible. This occurrence establishes the fact of pregnancy, whatever doubts may have previously

[1] American Journal of the Med. Sciences, p. 37, July, 1842.
[2] Amer. Med. Intel., March 15, 1841, p. 369.
[3] Casper's Wochenschrift, Jan. 11, 18, 1845, cited by Dr. Charles West, in Brit. and For. Med. Rev., Oct. 1845, p. 525.
[4] Op. cit.
[5] Lehrbuch der Physiologischen Chemie, 1ste Band., Leipz., 1842, cited in Brit. and For. Med. Rev., April, 1844, p. 439.

existed. Where there is much corpulence, or where the fluid surrounding the fœtus is in such quantity as to throw obscurity around the case, it may be necessary, for the purpose of verifying the existence of pregnancy, to institute an examination *per vaginam*. This can rarely afford much evidence prior to the period of quickening; but, after this, the examination, by what the French term the *mouvement de ballottement*, may indicate the presence or the contrary of a fœtus in utero. This mode of examination consists in passing the forefinger of one hand into the vagina,—the female being in the erect attitude,—and giving the fœtus a sudden succussion by means of the other hand placed on the abdomen. In this way, a sensation is communicated to the finger in the vagina, which is often of an unequivocal character. During the latter months, the cervix uteri becomes progressively shorter.

Of late years, the application of the stethoscope has been used as a means of discrimination in doubtful cases. By applying this instrument to the abdomen of a pregnant female, after the fifth month, the pulsations of the fœtal heart are audible. This instrument may also indicate when the pregnancy is multiple, by the pulsations of two or more distinct hearts; according as it is double, triple, &c. It would appear, however, that auscultation affords but two main signs of pregnancy,—the pulsations of the fœtal heart, and a murmur, which, according to some, should, correctly speaking, be designated "uterine *souffle* or murmur." This murmur has been supposed to take place in the uterine artery, which serves for the nutrition of the placenta, and even to indicate the situation of the placenta: others have considered, that it is not connected with the placenta, but depends upon the increased vascularity and peculiar arrangement of the uterine vessels during the gravid state; but it has been questioned whether it be ever produced except by pressure on the maternal vessels. It is, indeed, positively stated, that the sound has been heard in cases of uterine and other tumours where there was no pregnancy; and in one case of fibrous tumour of the uterus, the author certainly heard it distinctly.

In addition to the placental or uterine murmur and the sounds of the fœtal heart, a third sound is occasionally heard, and one which is considered to be seated in the umbilical cord. This has been termed the "funic bellows' sound." It is of the bellows species; is synchronous with the first sound of the fœtal heart, and appears to depend upon a diminution in the caliber of the umbilical arteries, either through pressure, or stretching of the funis, or both combined. It is affirmed, too, by Prof. Nägele, that the movements of the fœtus may be distinguished by the stethoscope at a very early period of pregnancy.

The pulsations of the fœtal heart vary from 120 to 180 in the minute. Nägele[1] affirms, that he has occasionally found them,—momentarily however,—sink as low as 50 or 60. Professor Hamilton[2] refers to various cases, in which Drs. Sidey and Moir attended particularly to the action of the fœtal heart previous to breathing, in all of which its beats were 60 or less in a minute, before the establishment of respira-

[1] Dublin Journal of Medical Science, Jan. 1838.

[2] Practical Observations on Various Subjects relating to Midwifery, American Medical Library edition, part i. pp. 51, 93, and part ii. p. 123, Philad., 1837-8.

tion. Professor Hamilton affirms, that almost half a century had then elapsed since he remarked, that in infants which did not breathe upon birth, but in which the pulsation of the cord continued, the action of the heart did not exceed 60 pulsations in the minute till breathing took place, and then it became so frequent that it could not be numbered. This led him to take every opportunity—when he had occasion to introduce his hand into the uterus to extract the infant—to endeavour to ascertain the action of the heart before birth, and he in no instance discovered it to be more frequent than in the still-born infant whose cord pulsates. Yet neither Dr. Hamilton, nor any one of the gentlemen referred to, denies that pulsations, which have been referred to the fœtal heart, are heard by the stethoscope, varying from 120 to considerably upwards in the minute. The truth would seem to be, that in the cases examined by Professor Hamilton, owing to the influence of the parturient efforts on the innervation, and through it on the circulation of the fœtus, the pulsations of the fœtal heart were unusually depressed; but in every case, he would, doubtless, have found them isochronous with those of the umbilical cord, had he made the experiment. It is obvious, indeed, that they must be so, seeing that the umbilical arteries are but a part of the circulatory apparatus of the fœtus. In a case observed, at the author's request, by Dr. Vedder, then resident physician at the Philadelphia Hospital, it was noticed, that whilst the uterus was quiescent, the pulsations of the fœtal heart numbered 140 per minute; but that immediately succeeding a pain they were only 96, and gradually rose to 140. After delivery, the cord and fœtal heart beat respectively 134 in the minute.[1] Von Hoefft,[2] of St. Petersburg, has seen the influence of uterine contraction on the circulation of the fœtus exhibited in the most marked manner. During slight pains, the pulsations of the fœtal heart continue, but during more violent contractions, especially after the discharge of the waters, they are wholly interrupted, so that the fœtus may be presumed to be in a state of temporary asphyxia in the last periods of labour, and great danger may threaten it if the pains continue for a long time without interruption. The remarks of Professor Hamilton ought, therefore, to have no weight with the observer. They were imperfect, inasmuch as the pulsations of the fœtal heart were not attended to, whilst he numbered the beats of the cord; and, consequently, they conflict in no respect with the observations of other obstetrical physiologists, which show, that the sounds usually heard during pregnancy, and referred to the fœtal heart, are actually owing to the pulsations of that organ.

A case of triplets has been published in which the pulsations of three distinct fœtal hearts were clearly detected.

Lastly; many uneasy feelings, attendant upon gestation, are owing to the increased size of the uterus. These occur more especially during the latter half of pregnancy. The parietes of the abdomen may not yield with the requisite facility, so that pain may be experienced, especially at the part where the soft parietes join the false ribs. The pres-

[1] American Medical Intelligencer, Jan. 15, 1839, p. 311.
[2] Ibid., April 15, 1839, p. 31; also, Neue Zeitschrift für Geburtskunde, B. vi. s. 1.

sure of the uterus upon the vessels and nerves of the lower extremities occasions enlargement of the veins of the legs; transudation of the serous part of the blood into the areolar tissue, so as to cause considerable swelling of the feet and ankles; numbness or pricking of the lower limbs, and the most violent cramps, especially when the female is in the recumbent posture, so that she may be compelled to rise suddenly from bed several times in the course of the night. The same pressure exerted on the bladder and rectum, especially during the latter months, brings on a constant desire to evacuate the contents of those reservoirs.

h. *Duration of Pregnancy.*

The duration of human pregnancy has given rise to much discussion amongst medico-legal and obstetrical physiologists; and opinions still fluctuate. In the years 1825–6, a case occurred before the House of Lords, which exhibits this discordance in a striking point of view. It was the Gardner Peerage cause, in which the principal accoucheurs of the British metropolis,—including Sir Charles M. Clarke, Drs. Blegborough, D. Davis, A. B. Granville, Conquest, Merriman, Hopkins, Blundell, and Power,—were examined. Of seventeen medical gentlemen, who gave evidence, five maintained the opinion, that the period of human utero-gestation is limited to about nine calendar months,—from thirty-nine to forty weeks, or from two hundred and seventy to two hundred and eighty days,—and of course considered it to be an impossibility, that the claimant could have been the product of a three hundred and eleven days gestation. On the other side, of twelve medical gentlemen, all of whom appeared to agree that nine calendar months is the usual term of utero-gestation, most of them maintained the possibility, that pregnancy might be protracted to nine and a half, ten, or even eleven calendar months, and were, of course, in favour of the claimant in the cause.[1]

The difficulty, that arises in fixing upon the precise term, is owing to the impracticability, in ordinary cases, of detecting the time of conception. But few cases exist where conception can be dated from a single *coitus*.[2] An opportunity occurred, however, to Dr. Montgomery,[3] for observing the term of utero-gestation under circumstances admitting of no dispute. A lady, who had been for some time under his care, in consequence of irritable uterus, went to the seaside at Wexford, in the month of June, leaving her husband in Dublin. They did not meet again until the 10th of November, when he went to visit her, and, being engaged in a public office, returned to town on the following day. Conception followed his visit, and before the end of the month she began to experience some of the signs of pregnancy, and on the 28th of January she quickened. Her last menstruation had occurred on the 18th of October, or twenty-three days before the visit of her husband;

[1] The Medical Evidence, relative to the Duration of Human Pregnancy, as given before a Committee of the House of Lords, in 1825 and 1826, with notes, by Robert Lyall, M. D., Lond., 1826.

[2] For some such, see Guy, Principles of Forensic Medicine, P. 1, p. 167, London, 1843, and Taylor, Medical Jurisprudence, 2d Amer. from 3d Lond. edit., by Dr. Griffith, p. 468, Philad., 1850.

[3] An Exposition of the Signs and Symptoms of Pregnancy, &c., p. 257. Lond., 1837.

and on the 17th of August she was delivered. Parturition in this case, occurred exactly two hundred and eighty days from the time of conception.

The sensations of the female are fallacious guides; and, accordingly, as has been previously remarked, she is usually in the habit of reckoning from ten days after the disappearance of the catamenia; but impregnation might have taken place on the very day after their cessation, or not until a day prior to the subsequent period; so that, in this way, an error of at least ten days may occur in the estimate; and again, it does not *always* happen, that the menstruation, immediately succeeding, is arrested. The period of quickening, which generally happens about the eighteenth week of utero-gestation, does not afford us more positive evidence, seeing that it is liable to vary; being experienced by some females earlier, and by others somewhat later. We are, however, justified in stating, that the ordinary duration of human pregnancy is ten lunar months or *forty weeks;* but we have no less hesitation in affirming, that it may be protracted, in particular cases, much beyond this. We find in animals, where the date of impregnation can be rigidly fixed, and the usual term determined without difficulty, that numerous cases are met with in which the period is protracted, and there is no reason to doubt, that the same thing happens to the human female. Earl Spencer has communicated the results of his observations on cows for a number of years to the English Agricultural Society.[1] Of 764, 314 calved before the 284th day, and 310 after the 285th; so that the probable period of gestation, he thinks, ought to be considered 284 or 285 days, and not 270, as stated in the book upon Cattle, published under the superintendence of the Society for the Diffusion of Useful Knowledge. The extremes in his observations were 220 and 313 days. In the observations of Mr. C. N. Bement, of Albany, cited by Dr. T. R. Beck,[2] the extremes in sixty-two observed cases were 213 and 336. Mr. Bement, however, doubts the accuracy of the first, for in no other instance did the period fall below 260 days.

The observations of Earl Spencer[3] have suggested an interesting question in regard to man. He noticed, that cows in calf to a particular bull belonging to him carried their calves about four days longer than those in calf to any other bull;—the average period of gestation being in them $290\frac{1}{4}$ days.

In a case detailed by Dr. Dewees,[4] an opportunity occurred for dating with precision the time of fecundation. The case is likewise interesting in another respect, as demonstrating, that fecundation does not necessarily arrest the succeeding catamenial discharge. The husband of a lady, who was obliged to absent himself many months, in consequence of the embarrassment of his affairs, returned one night clandestinely,—his visit being known only to his wife, her mother, and Dr. Dewees himself. The lady was, at the time, within a week of her menstrual period; and, as the catamenia appeared as usual, she was induced

[1] Journal of the English Agricultural Society, part. ii., 1839.
[2] American Journal of the Medical Sciences, Oct. 1845, p. 520.
[3] Hall, Lond. Med. Gazette, May 6, 1842.
[4] A Compendious System of Midwifery, 10th edit., p. 130, Philad., 1843.

to hope, that she had escaped impregnation. Her catamenia did not, however, make their appearance at the next period; the ordinary signs of pregnancy supervened; and in nine calendar months and thirteen days from the visit of her husband, she was delivered. In his evidence before the House of Peers, in the case before alluded to, Dr. Granville stated his opinion, that the usual term of utero-gestation is as we have given it; but he, at the same time, detailed the case of his own lady, in whom it had been largely protracted. Mrs. Granville passed her menstrual period on the 7th of April, and on the 15th of August following she quickened;—that is, four months and six or seven days afterwards. In the early part of the first week in January her confinement was expected, and a medical friend desired to hold himself in readiness to attend. Labour pains came on at this time, but soon passed away; and she went on till the 7th of February, when labour took place, and was speedy. The child was larger and stronger than usual, and was considered by Dr. Granville,—as well as by Dr. A. T. Thomson, Professor of Materia Medica in the University of London,—to be a ten months' child. Now, if, in this case, we calculate, that conception occurred only the day before the interruption of menstruation, three hundred and six days must have elapsed between impregnation and birth; and if the middle period between the last menstruation and the interruption be taken, the interval must have been three hundred and sixteen, or three hundred and eighteen days. A similar case has been related by Dr. R. H. McIlvain,[1] of North Carolina. A woman, of character above suspicion, on the 1st of July, 1847, had intercourse with her husband, whose business had compelled him to absent himself for more than a year in a distant State. On the nights of the 2d, 3d, and 4th of July, the intercourse was repeated; but not subsequently. On the 23d of April, 1848, she was delivered of a child, which weighed nine pounds. Now, if fecundation had occurred on the 1st of July, the duration of pregnancy must have been 296 days; if on the 4th, 293 days. Dr. McIlvain adds, that the large size of the child was in favour of gestation having been longer than usual. The woman had borne three children previously, none of which weighed more than eight pounds.

The limit, to which the protraction of pregnancy may *possibly* extend, cannot be assigned. It is not probable, however, that it ever varies largely from the ordinary period. The University of Heidelberg allowed the legitimacy of a child, born at the expiration of thirteen months from the date of the last connubial intercourse; and a case was decided by the Supreme Court of Friesland, by which a child was admitted to the succession, although it was not born till three hundred and thirty-three days from the husband's death; or only a few days short of twelve lunar months. These are instances of judicial philanthropy, and, perhaps, we might add, credulity. Still, although extremely improbable, we cannot say that they are impossible. This much, however, is clear, that real excess over two hundred and eighty days is by no means frequent; and we think, in accordance with the civil code now in force in France, that the legitimacy of an infant, born three hundred days after

[1] American Journal of the Medical Sciences, July, 1848, p. 247.

the dissolution of marriage, may be contested; although we are by no means disposed to affirm, that if the character of the woman be irreproachable, the decision should be on the side of illegitimacy. Professor Hamilton, indeed, says he is "quite certain," that the term allowed by the French code is too limited, and is inclined to regard *ten calendar months*, which he believes to be the established usage of the Consistorial Court of Scotland, as a good general rule, liable to exceptions upon satisfactory evidence that menstruation had been obstructed for a certain period.[1]

In the year 1844, a case of gestation protracted to 317 days was admitted in Cambria county, Pennsylvania;[2] and in 1846, another of 313 days at the Lancaster Quarter Sessions.[3] The charge of the presiding judge, Ellis Lewis, in the latter case, was sound and satisfactory. Whilst he expressed the belief, that protracted gestation for the period of 313 days is *unusual* and *improbable*, he regarded it as not *impossible;* but properly added "that the evidence to establish the existence of such a departure from the usual period should be clear and free from doubt."

A like uncertainty exists as to the earliest period at which a child is *viable* or capable of carrying on an independent existence. The period is generally fixed at near the end of the seventh month; but children have lived for some time, that have been born earlier. Much evidence was brought forward in a case in Scotland, to show that it is possible for a child that was born at the conclusion of 24 weeks of utero-gestation to live some months. In that case, the Presbytery decided in favour of the legitimacy of one born alive within 25 weeks after marriage.[4]

An interesting case has been published in this country by Dr. Shipman.[5] A woman, who considered herself to be at the commencement of the sixth month of utero-gestation, was prematurely delivered in consequence of a fall. The appearance of the child indicated no farther advance. It was barely alive, with little motion, and was too feeble to cry; had no nails; no hair; and the cranium was imperfectly ossified. At the end of the seventh week, it was weighed for the first time, when its weight was found to be one pound ten ounces, which Dr. Shipman thinks was probably the true weight when it was born. When ten months old it weighed ten pounds eight ounces, and was lively, playful, and healthy. It was not measured at the time of birth, and no hopes of its living were entertained.

The difficulty, in such cases, of fixing the exact date of conception must necessarily render all computation in regard to the precise age of the child uncertain.

[1] Op. cit., Amer. Med. Library edit., p. 59.

[2] Commonwealth *vs.* Jeremiah Wilson Porter; indicted for Fornication and Bastardy, January Term, 1844; reported by Dr. A. Rodrigue, in American Journal of the Medical Sciences, Oct. 1845, p. 338.

[3] Commonwealth *vs.* Elijah F. Hoover; in Medical Examiner, for June, 1846, p. 381; and in American Journal of the Medical Sciences, for Oct. 1846, p. 536.

[4] Lond. Med. Gaz., xvii. 92.

[5] American Journal of the Med. Sciences, April, 1843, p. 499.

i. *Parturition.*

At the end of seven months of utero-gestation, and even a month earlier, the fœtus is capable of an independent existence; provided, from any cause, delivery should be hastened. This is not, however, the *full period*, and although labour may occur at the end of seven months, the usual course is for the fœtus to be carried until the end of about ten lunar months. If it be extruded prior to the period at which it is able to maintain an independent existence, the process is termed *abortion* or *miscarriage;* if between this time and the full period, it is called *premature labour.* From certain records, abortion or premature labour has been estimated to occur, on the average, once in 78½ cases. In the Gebäranstalt of Vienna, the inmates of which are chiefly unmarried, the ratio appears to be more than double, or 1 in 38·13.[1]

With respect to the causes, that give rise to the extrusion, we are in utter darkness. It is in truth as inexplicable as any of the other instinctive operations of the living machine. Yet although this is generally admitted, the discussion of the subject occupies a considerable space in the works of some obstetrical writers. Our knowledge appears to be limited to the fact, that when the fœtus has undergone a certain degree of developement, and the uterus a corresponding distension and organic changes, its contractility is called into action, and the uterine contents are beautifully and systematically expelled. Nor can we pronounce upon the degree of distension nor appreciate the organic changes that shall give occasion to the exertion of this contractile power. At times, it supervenes after a few months of utero-gestation so as to produce abortion; at others, it happens when the fœtus is just *viable;* and at others, again, and in the generality of cases, is not elicited until the full period. In cases of twins the uterus will admit of still greater distension before its contractility is aroused.

It has been maintained by M. Berthold,[2] Dr. Tyler Smith[3] and M. Leray,[4] that parturition, like menstruation, is an ovarian phenomenon; that the muscular excitability of the uterus at the full period is dependent upon ovarian excitement; and that the supervention of its expulsive contractions on the 280th day, or thereabouts, after conception, is a reflex phenomenon, of which the eleventh periodical access of ovarian excitement, corresponding to the eleventh menstrual period, is the exciting cause; but the evidence brought forward in support of the position is far from establishing it. The hypothesis would require a more extensive inquiry into the phenomena, presented not only by the human female, but by animals, in which the period of parturition would have to be a multiple of the period of œstruation or heat; for it has been before remarked that the œstruation of animals and menstruation have been regarded as the same form of ovulation. Dr. Smith

[1] Wilde, Austria, &c., p. 222, Dublin, 1843.

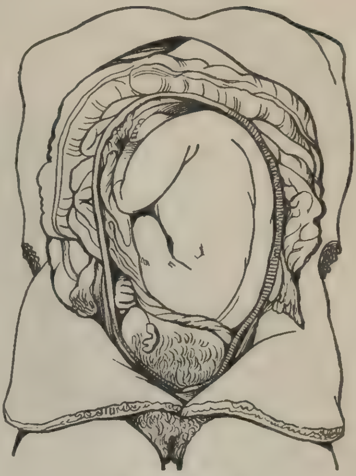
[2] Comptes Rendus, 27 Mai, 1844; and Archives Générales de Médecine, Juin, 1844.

[3] Parturition and the Principles and Practice of Obstetrics, Amer. edit., p. 127, Philad., 1849.

[4] Cited in London Lancet, Jan. 15, 1848.

affirms, that observation of animals has tended to confirm the view; but he does not furnish the facts in sufficient number to lead to anything like conviction of the truth of the hypothesis.

Fig. 404.



Natural Labour.

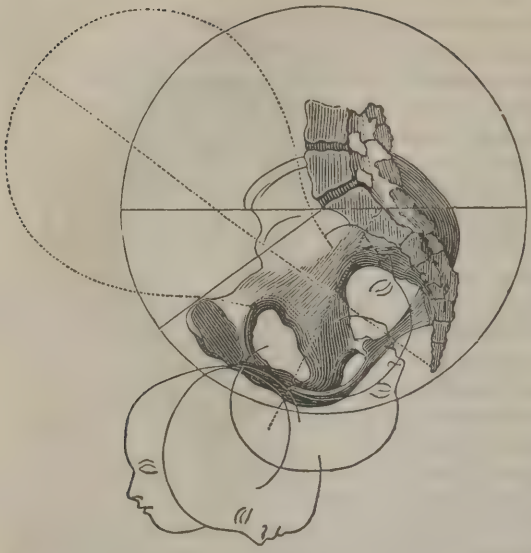
In regard to the action of the muscles specially concerned in the process, it would seem, that the diaphragm and abdominal muscles are excited to action through an excitor influence conveyed from the uterus to the spinal cord; whilst the contractions of the uterus take place independently of all connexion with the nervous centres,—like the peristole of the intestines, and the systole of the ventricles of the heart. The fœtus has been observed to be expelled after the cessation of the respiratory movements of the mother. This, as has been suggested,[1] has probably occurred in consequence of the uterine fibres retaining their power of contraction longer than those of muscles supplied by cerebro-spinal nerves.

A day or two preceding labour, a discharge is occasionally observed from the vagina of a mucous fluid more or less streaked with blood. This is termed the *show*, because it indicates the commencement of some dilatation of the neck, or mouth of the womb,—the forerunner of *labour* or *travail.* The external organs at the same time become tumid and flabby. The orifice of the uterus, if an examination be made, is perceived to be enlarging; and its edges are thinner. Along with this, slight grinding pains are experienced in the loins and abdomen. After an uncertain period, pains of a very different character come on, which commence in the loins, and appear to bear down towards the os uteri. These are not constant, but recur at first after long intervals, and subsequently after shorter,—the body of the uterus manifestly contracting with great force, so as to press the ovum down against the mouth of the womb, and dilate it. In this way, the membranes protrude through the os uteri with their contained fluid, the pouch being occasionally termed *bag of waters.* Sooner or later, the membranes give way; the *waters* are discharged, and the uterus contracts so as to embrace the body of the child, which was previously impracticable, except through the medium of the liquor amnii.

At the commencement of labour, the child's head has not entered the pelvis, the occiput being generally towards the left acetabulum; but when the uterine contractions become more violent, and are accompanied by powerful efforts on the part of the abdominal muscles, the head enters the pelvis; the mouth of the womb becomes largely dilated,

[1] Carpenter, Human Physiol., p. 153, Lond., 1842.

Fig. 405.



Rotation of the Head in its exit.

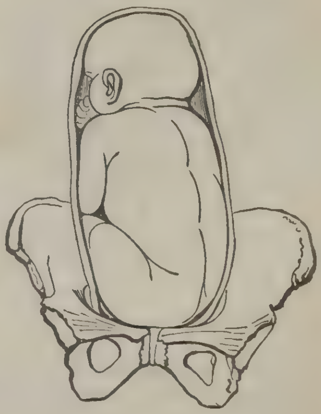
and the female is in a state of agitation and excitement, owing to the violence of the efforts and the irresistible desire she has of assisting them as far as lies in her power. When the head has entered the pelvis, in the position in which the long diameter corresponds to the long diameter of the pelvis, it describes, laterally, an arc of a circle, the face passing into the hollow of the sacrum, and the occiput behind the arch of the pubis. By the continuance of the pains, the head presents at the vulva. The pains now become urgent and forcing. The os coccygis is pushed backwards, and the perineum is distended,—at times so considerably as to threaten, and even undergo laceration; the anus is also forced open and protruded; the nymphæ and carunculæ of the vagina are effaced; the labia separated, and the head clears the vulva, from the occiput to the chin, experiencing a vertical rotation as depicted in Fig. 405. When the head is extruded, the shoulders and rest of the body readily follow on account of their smaller dimensions. The child, however, still remains attached to the mother by the navel-string, which has to be tied, and divided at a few fingers' breadth from the umbilicus. After the birth of the child, the female has generally a short interval of repose; but after a time, slight bearing down pains are experienced, owing to the contraction of the uterus for the separation of the placenta and membranes of the ovum, called the *secundines* or *afterbirth.*

The process of parturition is accomplished in a longer or shorter time in different individuals, and in the same individual in different labours, according to the particular conditions of the female and fœtus. The parts, however, when once dilated, yield much easier afterwards to similar efforts, so that the first labour is generally the most protracted. After the separation of the secundines, the female is commonly left in a state of debility and fatigue; but this gradually disappears. The uterus also contracts; its vessels become tortuous, small, and their orifices are plugged up. For a short time, blood continues to be discharged from them; but as they become obliterated by the return of the uterus to its usual size, the discharge loses its sanguineous character, and is

replaced by one of a paler colour, called *lochia*, which gradually disappears, and altogether ceases in the course of two or three weeks after delivery. For a day or two after delivery, coagula of blood form in the interior of the uterus, especially in the second and subsequent labours, which excite the organ to contraction for their expulsion. These contractions are accompanied with pain, and are called *after-pains;* and as their object is the removal of that, which interferes with the return of the uterus to its proper dimensions, it is obvious that they ought not to be officiously interfered with.

Whilst the uterus is contracting its dimensions, the other parts gradually resume the condition they were in prior to delivery; so that, in the course of three or four weeks, it may be impracticable to pronounce positively whether delivery has recently taken place or not. The presence of shining broken streaks, like the remains of cracks, in the skin of the abdomen, caused by previous distension of the abdominal parietes, has been regarded as a sign of some value of former delivery; but they are often wanting where delivery has really taken place; and it will be readily understood, that any cause of distension may produce them. These marks are sometimes accompanied by a brown line, extending from the pubis to the umbilicus;[1] and accompanying this dark abdominal line, Dr. Montgomery, in a few instances, has observed another appearance of a similar kind, which consists of a dark coloured circle or areola surrounding the umbilicus, extending in breadth about a quarter of an inch all around it, and generally, but not always, varying in depth of tint according to the colour of the hair, eyes, and skin of the woman. Unlike the mammary areola, there is no turgescence or elevation of it above the surface of the surrounding skin, nor are there any prominent follicles upon its disk. Whether it be ever produced under circumstances unconnected with pregnancy remains to be determined by farther observation.

Fig. 406.



Breech Presentation.

Labour, as thus accomplished, is more deserving of the term in the human female than in animals; and this is partly owing to the large size of the fœtal head, and partly to the circumstance, that in the animal the axis of the pelvis is the same as that of the body; whilst in the human female, the axis of the brim, as represented by the dotted straight lines in Fig. 405, forms a considerable angle with that of the outlet. In rare cases, the child is extruded without labour-pains. The author was called in the night to a female, who declared to him, that she was awakened by a slight

[1] Montgomery, Signs and Symptoms of Pregnancy, 6th edit., p. 171, Lond., 1842; Dublin Journal of Med. Sciences, May, 1844, p. 298: see, also, Dr. R. Turner, Lond. and Edinb. Monthly Journal of Med. Sciences, Aug. 1842, and Sept. 1844; and Dr. J. R. Cormack, Ibid., Feb. 1844.

abdominal uneasiness, when she found both the child and secundines expelled; and other cases of a like kind are on record. These facts should be borne in mind in cases of alleged infanticide.

The duration of labour varies according to numerous circumstances. There is reason to believe, that it is more tedious in civilized than in savage life; and in colder than in warmer climates. The following table is the result of 311 observed cases in the Edinburgh Royal Maternity Hospital, as reported by Professor Simpson.[1] It reads thus:—the whole labour was completed in one hour in four cases; in two hours in four cases, and so on.

Duration in hours.	Whole labour.	Duration in hours.	Whole labour.
1	4	13	23
2	4	14	14
3	7	15	8
4	16	16	6
5	17	17	6
6	16	18	8
7	28	19	10
8	21	20	3
9	17	25	22
10	20	30	12
11	20	35	5
12	12	Above 36	14

The position of the child—with the face behind and the occiput before—constitutes the usual presentation in natural labour. Of twelve thousand six hundred and thirty-three children born at the *Hospice de la Maternité* of Paris, twelve thousand one hundred and twenty, according to M. Jules Cloquet, were of this presentation; sixty-three had the face turned forward; one hundred and ninety-eight were breech presentations (Fig. 406); in one hundred and forty-seven the feet presented; and in three, the knees. All these, however, are cases in which labour can be effected without assistance; the knee and feet presentations being identical—as regards the process of delivery—with that of the breech. But, whenever any other part of the fœtus presents, the position is unfavourable, and requires that the hand should be introduced into the uterus, with the view of bringing down the feet, and converting the case into a foot presentation. The marginal figure of a presentation of the right superior extremity sufficiently shows, that labour could not be accomplished without the efforts of art.

Fig. 407.

Arm Presentation.

The following table, drawn up from data furnished by M. Velpeau,[2]

[1] Monthly Journal and Retrospect of the Medical Sciences, Nov. 1848, p. 333.

[2] Traité Elémentaire de l'Art des Accouchemens, Paris, 1829; or Meigs's translation, 2d edit., Philad., 1838.

shows the comparative number of presentations, according to the experience of the individuals mentioned.

TABLE EXHIBITING THE RATIO OF PRESENTATIONS IN 1000 CASES.

	According to							
	Merriman.	Bland.	Mde. Boivin.	Mde. Lachapelle.	Nägele.	Lovati.	Hospital of the Faculté.	Boer.
Regular, or of the vertex,	924	944	969	933	933	911	980	
I. *Occipito-anterior*, . .	908		944	910		895		
a. Occipito-cotyloid, (left)			760	717		537		
Do. (right)			179	209				
b. Occipito-pubian, . .			0·29					
II. *Occipito-posterior*, .			9·4	9				
a. Fronto-cotyloid (left)			5·3	7·3				
b. Do. (right)			4·4	2·9				
Face presentation, . .	2·2	2·6	3·6	4·6				8·8
Mento-iliac (right) . .				2·6				
Of the pelvis, . . .	36	28	29	36	47			29
Of the foot, ...	12·7	9·4		14				10·3
Of the knees, . . .			0·19	0·40				
Of the breech, . . .	23	13	18	22				19
Of the trunk, ...			4·6	5·3	4·8			
Requiring Forceps, . .	6·6	4·7	4·6	3·4	36			5·7
——— Turning, . .	16	4·7		7·8	7·2			5·9
——— Cephalotomy,	3·3	5·2	4·77	0·53	2·4			1·5

In twin labours, the children may both present by the head; or one by the head and another by the breech, or both be footling cases.

Fig. 408.

Twin case.

It is found, that the period of the twenty-four hours has some influence upon the process of parturition;—about five children being born during the night for four during the day.

The parturient and child-bed condition is not devoid of danger to the female; yet the mortality is less than is generally perhaps imagined. In some of the great lying-in institutions it has been enormous; and in the Gebäranstalt of Vienna is still estimated at 1 in 30·87! The number of deaths, during labour, and subsequently, connected therewith, has been stated to be in Berlin as 1 in 152; in Königsberg, 1 in 168; and in Wirtemberg, 1 in 175;—a proportion much less than during the last century. In 1475 women delivered under the superintendence of the Edinburgh Royal Maternity Hospital, eleven deaths occurred,—or 1 in 134.[1] Dr. Collins[2] states, that of 16,414 women, delivered in the Dublin Lying-in Hospital, 164 died, being in the pro-

[1] Monthly Journal and Retrospect of the Medical Sciences, November, 1848, p. 337.
[2] Practical Treatise on Midwifery, p. 366, Lond., 1835.

portion of 1 in 100; and if, he observes, we deduct from this number the deaths from puerperal fever, which may be considered *accidental*, the proportion becomes greatly diminished, or 1 in 156 deliveries; and again, if we subtract the deaths from causes not the results of childbirth, the mortality, from effects arising in consequence of parturition, is vastly reduced to 1 in 244. In the year 1839, childbirth was fatal to 2915 women throughout England and Wales. Of 1,000,000 females living, 368 died from this cause in 1838, and 372 in 1839. About 5 births in 1000, it was estimated, were fatal to the mother.[1] In 1840, the ratio was greater, or about 1 in 187.[2] It has been already remarked, that these fatal cases occur more frequently in male than female births. From the returns of Drs. Clarke and Collins there are reports in the Dublin Hospital of the sex of the child in 368 cases in which the mother died from labour or its consequences. In 231, the child was male; in 137, female; or the proportion of males to females was as 168 to 100. Taking these statistical facts as data, Prof. Simpson,[3] of Edinburgh, infers, that annually, in Great Britain, "the valuable lives of 500 mothers (to speak within the terms) are lost in childbirth," through the influence and agency of the sex and size of the male infant.

The further details on the subject of parturition belong more appropriately to obstetrics.

j. *Lactation.*

When the child has been separated from the mother, and continues to live by the exercise of its own vital powers, it has still to be dependent upon her for nutriment adapted to its tender condition. Whilst in utero, this nutriment consists of fluids placed in contact with it; but after birth, a secretion serves the purpose, which has to be received into the stomach and undergo the digestive process. This secretion is the *milk*. It is prepared by the *mammæ* or *breasts*, the number, size, and situation of which are characteristic of the human species. Instances are, however, on record, of three or more distinct mammæ in the same individual. Two such are described by Dr. G. C. M. Roberts, of Baltimore.[4] At times, there are two nipples on one breast. Three cases of the kind are given by Tiedemann, and one by Dr. Chowne;[5] and a case has been recorded by M. Marotte,[6] in which there was a supernumerary mamma in each axilla. In some instances, the supernumerary breasts have been on other parts of the body.

Each breast contains a mammary gland, surrounded by the fat of the breast, and resting on the pectoralis major muscle. It is formed of several lobes, united by somewhat dense areolar tissue, and consisting of smaller lobules, which seem, again, composed of round granula-

[1] W. Farr, in Third Annual Report of the Registrar-General of Births, Deaths, and Marriages in England, p. 74, London, 1841.
[2] W. Farr, in Fourth Annual Report, &c., &c., p. 219, Lond., 1842.
[3] Edinb. Med. and Surg. Journal, Oct. 1844.
[4] Baltimore Medical and Surgical Journal, ii. 497, Baltimore, 1834.
[5] Lond. Lancet, July 2, 1842, p. 465.
[6] Archives Générales de Médecine, Janvier, 1850, p. 114.

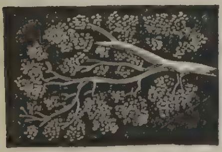
Fig. 409.

Milk Ducts in Human Mamma.

The ducts are filled with wax. (Sir Astley Cooper.)

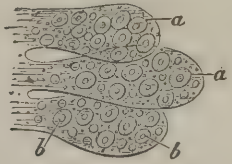
tions, of a rosy-white colour, and about the size of a poppy-seed. These granules or acini, according to Reil,[1] cannot be distinguished in

Fig. 410.



Commencement of Milk Ducts as exhibited in a mercurial injection. (Sir Astley Cooper.)

Fig. 411.



Ultimate Follicles of Mammary Gland.

a, a. Secreting cells. *b, b.* The nuclei.

the mammæ of the virgin. The glandular granules give origin to excretory ducts, called *tubuli lactiferi* seu *galactophori*, which are tortuous, extensible, and transparent; and enlarge and unite with each

[1] Schlemm, art. Brüste, in Encyclop. Wörterb. der Medicin. Wissenschaft., vi. 332, Berlin, 1831.

other, so that those of each lobe remain distinct from, and have no communication with, the ducts of any other lobe. All these finally terminate in sinuses, or reservoirs, near the base of the nipple, which are fifteen or eighteen in number, and open on the nipple, without having any communication with each other. The size and shape of the breast are chiefly caused by the areolar tissue in which the mammary gland is situate: this is covered by a thin layer of skin, which is extremely soft and delicate; and devoid of folds. In the middle of the breast is the tubercle, called *nipple*, *mammella*, or *teat*,—a prominence consisting of an erectile spongy tissue, differing in colour from the rest of the breast.

The nipples do not project directly forwards, but forwards and outwards, for wise purposes, which have been thus depicted by Sir Astley Cooper:[1]—"The natural obliquity of the mammella or nipple forwards and outwards, with a slight turn of the nipple upwards, is one of the most beautiful provisions in nature both for the mother and her child. To the mother, because the child rests upon her arm and lap, in the most convenient position for sucking; for if the nipple and breast had projected directly forwards, the child must have been supported before her in the mother's hands in a most inconvenient and fatiguing position, instead of its reclining upon her side and arm. But it is wisely provided by nature, that when the child reposes upon its mother's arm, it has its mouth directly applied to the nipple, which is turned outwards to receive it, whilst the lower part of the breast forms a cushion upon which the cheek of the infant tranquilly reposes."

The erection of the nipple, which is so manifest during the process of suckling, and can be readily produced by handling it, has been supposed to be owing to an arrangement similar to that of the corpora cavernosa penis, or to a venous circle surrounding the nipple;[2] but Sir Astley Cooper attributes it simply to an afflux of blood into the capillaries of the part.

Around the nipple is the *areola*, which is of a rosy hue in youth but becomes darker in the progress of life, and the capillary system of which is so delicate as to blush, like the countenance, under similar emotions. The changes, produced on the areola by gestation, have been already described. The skin, at the base of the nipple, and on its surface, is rough, owing to the presence of a number of sebaceous follicles, called by Sir Astley Cooper "tubercles of the areola," which secrete a fluid for the lubrication of the part, and for defending it from the action of the secretions from the mouth of the infant during lactation. Numerous arteries, veins, nerves, and lymphatics,—the anatomical constituents of organic textures in general,—enter into the composition of the mammæ and nipples.

The mammary gland of the male is analogous to that of the female, but much smaller.

The secretion of milk is liable to longer intermissions than any other function of the kind. In the unmarried and chaste female, although

[1] On the Anatomy of the Breast, p. 12, London, 1840.

[2] Prof. Sebastian, Tijdschrift voor Natuurlijke Geschiedenis en Physiologie, door J. Van der Hoeven en W. H. de Vriese, 2de Deel, bl. i., Amsterdam, 1835.

the blood, whence milk is formed, may be constantly passing to the breast, no secretion takes place from it. It is only during gestation and some time afterwards, that, as a general rule, the necessary excitation exists to produce it. Yet although largely allied to the generative function,—the mammæ undergoing their chief developement at puberty, and becoming shrivelled in old age,—the secretion may arise independently of impregnation; for it has been witnessed in the unquestioned virgin, the superannuated female, and even in the male sex. The fact as regards the unimpregnated female is mentioned by Hippocrates. M. Baudelocque[1] states, that a young girl at Alençon, eight years old, suckled her brother for the space of a month. Dr. Gordon Smith[2] refers to a manuscript in the collection of Sir Hans Sloane, which gives an account of a woman, at the age of sixty-eight, who had not borne a child for more than twenty years, and nursed her grandchildren, one after another. Professor Hall, of the University of Maryland, related to the author the case of a widow, aged fifty, whom he saw giving suck to one of her grandchildren, although she had not had a child of her own for 20 years previously. The secretion of milk was solicited by putting the child to her breast during the night, whilst weaning it. Dr. Francis, of New York, describes the case of a lady, who, 14 years previously, was delivered of a healthy child after a natural labour. "Since that period," he remarks, "her breasts have regularly secreted milk in great abundance, so that, to use her own language, she could at all times easily perform the office of a nurse;" and Dr. Kennedy,[3] of Ashby de la Zouch, has described the case of a woman, who menstruated during lactation; suckled children uninterruptedly through the full course of forty-seven years, and, in her eighty-first year, had a moderate, but regular supply of milk, which was rich and sweet, and did not differ from that yielded by young and healthy mothers. In a note, with which the author was favoured by Dr. Samuel Jackson—formerly of Northumberland county, Pa., now of Philadelphia—a case is described, of a lady, certainly above sixty-five years of age, who nursed one of her daughter's twins. She had not borne a child for many years, and was suddenly endowed with a full flow of milk. A lady of Northumberland observed to Dr. Jackson, "that she could not but admire the beautiful fulness and contour of her bosom." Dr. Richard Clarke,[4] of Union Town, South Alabama, has recorded the case of a lady, who had never borne a child, and was requested to take charge of an infant, during the illness of its mother. In the course of the night, the infant became restless and fretful, and the lady—to quiet it—put her nipple into its mouth. This was done from time to time, until the milk began to flow. An interesting fact, connected with this case, was, that some time afterwards she conceived, and at the expiration of the usual term was delivered of a fine child. Dr. Clarke refers to other cases, which would appear to show, in another form, the intimate and mysterious sympathy that exists between the

[1] Art. d'Accouchement, i. 188, Paris, 1822. [2] Forensic Medicine, p. 484.
[3] Medico-Chirurgical Review for July, 1832.
[4] American Medical Intelligencer, April 16, 1838, p. 19.

mammæ and the uterus. Dr. Green[1] has published the case of a lady, aged 47 years, the mother of four children, who has had abundance of milk for 27 years past. A period of exactly four years and a half occurred between each birth, and the children were permitted to take the breast till they were running about at play. At the time when Dr. Green wrote, she had been nine years a widow, and was obliged to have her breasts drawn daily, the secretion of milk being so copious. In the Samoan group of islands, the mothers often suckle their children until they are six years old; and Captain Wilkes was informed of an instance where a woman gave nourishment to three children of different ages,—the eldest removing the youngest at times by force from the mother's breast.[2] Dr. McWilliam[3] states, that the inhabitants of Bona Vista are accustomed to provide a wet-nurse, in cases of emergency, in any woman who has once borne a child, and is still within the age of child-bearing, by continued fomentation of the mammæ with a decoction of the leaves of jatropha curcas, and by suction of the nipple.

According to M. Desormeaux,[4] some women are able to continue suckling almost indefinitely, provided the child be put to the breast. It is not uncommon, he says, in France, to see nurses suckle three children in succession, comprising a period probably of from 30 to 36 months; and cases are not rare where women have given suck for four years, and four years and a half. He saw a nurse from Normandy, who had suckled several children successively on the same milk for upwards of five years; and a lady, worthy of all credit, informed him, that she knew a woman who had nursed five children in succession, so that her lactation continued at least seven years. Mr. Erman[5] found, that the Tunguzian women suckle their children for a very long period. In Garmaztakh, he saw a boy, four years old, frequently quieted with the milk, which more properly belonged to his youngest brother. He saw several similar examples amongst the Samoyed women, and learned from a medical gentleman in Tobolsk, that the Ostyok fisherwomen can give milk at all times, "almost like cows."

But these, and cases of a similar nature, of which there are many on record,[6] do not possess the same singularity as those of the function being executed by the male. We have, however, the most unquestionable authority in favour of the occurrence of such cases. A bishop of Cork[7] relates the case of a man who suckled his child after the death of his wife. Humboldt adduces one of a man, thirty-two years of age, who nursed his child for five months on the secretion from his breasts; Captain Franklin[8] gives a similar instance; and Professor Hall, of the University of Maryland, exhibited to his obstetrical class, in the year 1827, a coloured man, fifty-five years of age, who had large, soft, well-formed mammæ; rather more conical than those of the female, and

1 New York Journal of Medicine and Surgery, September, 1844.
2 Narrative of the United States Exploring Expedition, &c., &c., ii. 138, Philad., 1845.
3 Report of the Niger Expedition, London Med. Gazette, Jan. 1847.
4 Art. Lactation, Dict. de Méd., xxii. 425, Paris, 1838.
5 Travels in Siberia; translated from the German by W. D. Cooley, ii. 527, London, 1848.
6 Elliotson's Blumenbach, 4th edit., p. 509, Lond., 1828.
7 Philos. Trans., xli. 813.
8 Narrative of a Journey to the Polar Sea, p. 157.

projecting fully seven inches from the chest; with perfect and large nipples. The glandular structure to the touch seemed to be exactly like that of the female. This man, according to Professor Hall, had officiated as wet-nurse for several years in the family of his mistress; and he represented, that the secretion of milk was induced by applying the children, intrusted to his care, to the breasts during the night. When the milk was no longer required, great difficulty was experienced in arresting the secretion. It may be added, that his genital organs were fully developed. In the winter of 1849–50, an athletic man, twenty-two years of age, presented himself at the Clinic of the Jefferson Medical College of Philadelphia, whose left mamma, without any assignable cause, became greatly developed, and secreted milk copiously.[1] It appears, therefore, that the secretion of milk may be caused, independently of a uterus, by soliciting the action of the mammary glands; but that this is a mere exception to the general rule, according to which the secretion is as intermittent as gestation itself.

It has been stated, as one of the signs of pregnancy, that the breasts become enlarged and turgid, denoting the aptitude for the formation of milk; and it not unfrequently happens, that, towards the middle and later periods of pregnancy, fluid distils from the nipples. This fluid, however, as well as that which flows from the breasts during the first two or three days after delivery, differs somewhat from milk, containing more serum and butter, and less casein; and is conceived to be more laxative, so as to aid the expulsion of the meconium. The first milk is called *colostrum*, *protogala*, &c., and, in the cow, constitutes the *biestings* or *beastings*. Generally, about the third day after confinement, the mammæ become tumid, hard, and even painful, and the secretion from this time is established, the pain and distension soon disappearing. The circumstances most worthy of note, connected with the colostrum of the cow, in a physiological point of view, are, according to Dr. John Davy[2]—who has carefully inquired into its chemical and other properties—the concentration of nutritive matter in it; the greater facility of its coagulation by rennet compared with older milk, and its greater power of resisting change when exposed to the action of atmospheric air,—qualities which, he thinks, fit it for the first food of the new being. Its ready coagulation may adapt it to the stomach, in which the gastric juice is probably at first in small quantity and feeble; and its power of resisting change, and remaining semi-fluid, may adapt a part of it to the intestines to promote the removal of the meconium; whilst its concentration as nutritive matter may fit it to perform for the calf the same part, that the substance of the egg performs, which enters the intestines during the latter stage of fœtal developement in birds, reptiles, and fishes. Whether the first milk of the human female possesses these characters has not been determined.

It is hardly necessary to discuss the views of M. Richerand,[3] who considers the milk to be derived from the lymph; or of others, who derive it from the chyle; of M. Raspail, who is disposed to think, that

[1] See a letter to the author by C. W. Hornor, in Medical Examiner, August, 1850.
[2] Transactions of the Medico-Chirurgical Society, 1845.
[3] Nouveaux Elémens de Physiologie, 7ème édit., Paris, 1817.

the mammary glands are in connexion, by media of communication yet unknown, with the mucous surface of the stomach, and that they subtract from the alimentary mass the salts and organizable materials which enter into the composition of the milk; or of M. Girard of Lyons, who gratuitously asserts, that there is in the abdomen an apparatus of vessels,—intermediate between the uterus and mammæ,—which continue inactive, except during gestation, and for some time after delivery; but, in those conditions, are excited to activity.[1] All these notions are hypothetical; and there is no reason for believing, that this secretion differs from others as regards the kind of blood from which it is separated. The separation occurs in the tissue of the gland, and the product is received by the lactiferous ducts, along which it is propelled by the fresh secretion continuously arriving, and by the contractile action of the ducts themselves,—the milk remaining in the ducts and sinuses, until at times, the mammæ are greatly distended and painful.

The excretion of the milk takes place at intervals. When the lactiferous ducts are sufficiently filled, a degree of distension and uneasiness is felt, which calls for the removal of the contained fluid. At times, the flow occurs spontaneously; but, commonly, only when solicited either by sucking or drawing the breast,—the secretion under such circumstances being very rapid, and the contraction of the galactophorous ducts such as to project the milk through the orifices in a thready stream.

Milk is a highly nitrogenized fluid, composed of water, casein, sugar of milk, certain salts,—as chloride of sodium, phosphate, and acetate of potassa, with a vestige of lactate of iron and earthy phosphate,—and a little lactic acid. Cow's milk consists of cream, and milk properly so called,—the *cream* consisting, according to Berzelius,[2] of butter, 4·5; cheese, 3·5; whey, 92·0;—and the *whey*, of milk and salt, 4·4;—the *milk* containing water, 928·75;—cheese, with a trace of butter, 28·01; sugar of milk, 35·00; chloride of potassium, 1·70; phosphate of potassa, 0·25; lactic acid, acetate of potassa, and lactate of iron, 6·00; and phosphate of lime, 0·30.

M. Raspail[3] defines milk to be an aqueous fluid, holding albumen and oil in solution by means of an alkali, or alkaline salt, which he suggests may be acetate of ammonia,—and, in suspension, an immense number of albuminous and oleaginous globules. The following table exhibits the discrepant results of the investigations of Brisson, Boyssou, Stipriaan Luiscius and Bondt, Schübler, and John, in 1000 parts of the milk of different animals—as given by Burdach.[4]

[1] Adelon, Physiologie de l'Homme, 2de édit. iv. 141, Paris, 1839.
[2] Medico-Chirurgical Transactions, vol. iii.
[3] Chimie Organique, p. 345, Paris, 1833.
[4] Physiologie als Erfahrungswissenschaft, 2te Auflage, Leipz., 1833.

	Observers.	Specific gravity.	Butter.	Cheese.	Sugar of milk.	Water.	Extract.
Ewe's milk.	Brisson,	10409					
	Boyssou,		38·24	51·26	20·73	886·19	3·45
	Luiscius,	10350	58·12	153·75	41·87	746·25	
	John,		54·68	31·25	39·06	875·00	
Cow's milk.	Brisson,	10324					
	Boyssou,		24·88	39·40	31·33	900·92	3·45
	Luiscius,	10280	26·87	89·37	30·62	853·12	
	Schübler,		24·00	50·47	77·00	848 53	
	John,		23·43	93·75	39·06	843·75	
Goat's milk.	Brisson,	10341					
	Boyssou,		29·95	52·99	20·73	892·85	3·45
	Luiscius,	10360	45.62	91·25	43·75	819·37	
	John,		11·71	105·45	23·43	849·39	
Mare's milk.	Brisson,	10364					
	Boyssou,		0·57	18·43	32·25	938·36	10·36
	Luiscius,	10450	0·00	16·25	87·50	896·25	
	John,		0·00	64·84	35·15	900·00	
Ass's milk.	Brisson,	10355					
	Boyssou,		0·92	19·58	39·97	932·60	6.91
	Luiscius,	10230	0·00	33·12	45·00	921·87	
	John,		0 00	11·71	46·87	941·40	
	Brisson,	10203					
	Boyssou,		32·25	11·52	46 08	903·92	6·91
	Luiscius,	10250	30·00	26·87	73·12	870·00	
	John,		23·43	15·62	39·06	921·87	

From this table, an approximation may be made as to the main differences between the milk of those animals; but it is not easy to explain the signal discrepancy amongst observers as to the quantity of the different materials in the milk of the same animal. Much, of course, may be dependent upon the state of the milk at the time of the experiment; but this can scarcely account for the whole discrepancy. From a great number of experiments, MM. Deyeux and Parmentier[1] classed six kinds of milk, which they examined, according to the following table, as regards the relative quantity of the materials they contained.

Casein.	Butter.	Sugar of Milk.	Serum.
Goat. Sheep. Cow.	Sheep. Cow. Goat.	Woman. Ass. Mare.	Ass. Woman. Mare.
Ass. Woman. Mare.	Woman. Ass. Mare.	Cow. Goat. Sheep.	Cow. Goat. Sheep.

The following table has been given more recently.[2] The constituents of the milk of the human family have been added from Clemm.[3] The

[1] Précis d'Expér., &c., sur les differentes espèces de Lait, Strasbourg, an vii., 1790.
[2] Carpenter, Principles of Physiology, 4th Amer. edit., p. 645, Philad., 1850.
[3] Scherer, in Wagner's Handwörterbuch der Physiologie, Art. Milch, 10te Lieferung, s. 470, Braunschweig, 1845. For other analyses, see Simon, Animal Chemistry, Sydenham Soc. edit., ii. 51, London, 1846.

analysis was made from milk obtained on the twelfth day after delivery.

	Cow.	Goat.	Sheep.	Ass.	Mare.	Woman.
Water, - -	861·0	868·0	856·2	907·0	896·3	905·809
Butter, - -	38·0	33·2	42·0	12·10	traces	33·454
Casein, - -	68·0	40·2	45 0	16·74	16·2	29·111
Sugar of milk and extractive matters,	29·0	52·8	50·0	62·31	87·5	31·537
Fixed salts, -	6·1	5·8	6·8			1·939

Human milk has, therefore, more sugar of milk and less cheesy matter than that of the cow; hence it is sweeter; more liquid; less coagulable; and incapable of being made into cheese. It has also albuminous, oleaginous, and saccharine ingredients combined, so as to adapt it admirably for the young as an aliment; and of all the secreted fluids it appears to be most nearly allied to blood in its composition.[1] M. Romanet[2] has affirmed, that the globules in cow's milk are wholly formed of butter, which exists as a pulp, enveloped in a white, translucent, elastic and resistent pellicle; and that the cyst is broken in churning, by which the butter escapes, and the pellicles floating about separately constitute the white particles that give consistence to buttermilk.

When human milk is first drawn, it is of a bluer colour than that of the cow. It rather resembles whey, or cow's milk much diluted with water. If allowed to rest, it separates, like the milk of other animals, into cream and milk,—the quantity of the cream being one-fifth to one-third milk. The milky portion, however, appears semitransparent like whey, instead of being white and opaque like that of the cow. During the first days of its remaining at rest, abundance of cream and a little curd are separated, and lactic acid is developed. The specific gravity of human milk was found by Dr. Rees to be 1·0358, and the solid contents 12 per cent. The specific gravity of the cream is 1·021.[3]

The quantitative analysis of the colostrum, after the investigations of Simon, Chevallier and Henry, Stipriaan Luiscius, Boussingault and Le Bel are thus given by Professor Scherer:—[4]

	Woman.	Cow.	Ass.	Goat.	Cow.
	(Simon.)		(Chevallier and Henry)		(Boussingault and Le Bel.)
Casein (Albumen), -	40·0	170·7	123·0	275·0	151·0
Butter, - - -	50·0	26·0	5·0	52·0	26·0
Sugar of milk, - -	70·0		43·0	32·0	36·0
Fixed salts, - -	3·1				3·0
Water, - - -	828·0	803·8	828·4	641·0	784·0
Fixed residue, - -	172·0	196·2	171·6	359·0	216·0

Of the 3·1 of fixed salts unalterable by heat, in Simon's analysis, 1·8 part was insoluble in water.

Casein—the nitrogenized constituent of milk—is distinguished from fibrin and albumen by its great solubility, and by not coagulating when

[1] Dr. G. O. Rees, Art. Milk, Cyclop. of Anat. and Physiol., Nov., 1841.
[2] Comptes Rendus, Avril, 1842.
[3] Sir Astley Cooper, On the Anatomy of the Breast, Amer. edit., p. 83, Philad., 1845.
[4] Op. cit., s. 451.

heated. This is regarded by Liebig[1] as "the chief constituent of the mother's blood. To convert casein into blood no foreign substance is required; and in the conversion of the mother's blood into casein no elements of the constituents of the blood have been separated."

The quantity and character of the milk differ according to the quantity and character of the food,—a circumstance, which was one of the greatest causes for the belief, that the lymphatics or chyliferous vessels convey to the mammæ the materials for the secretion. The milk is, however, situate in this respect like the urine, which varies in quantity and quality according to the amount and kind of solid or liquid food taken. The milk is more abundant, thicker, and less acid, if the female lives on animal food; and possesses the opposite qualities when vegetable diet is used. It is apt, also, to be impregnated with heterogeneous matters, taken up from the digestive canal. The milk and butter of cows indicate unequivocally the character of their pasturage, especially if they have fed on turnip, wild onion, &c. Medicine, given to the mother, may in this way act upon the infant. Serious—almost fatal—narcotism was induced in the infant of a professional friend of the author, by a dose of morphia administered to his wife.

It would seem, that occasionally the secretion of the two glands differs. A case has been related in which the milk of the right breast had a distinctly salt taste, whilst that of the opposite breast was of the ordinary sweetness. A difference also is at times observed in the number and size of the globules of the milk obtained from the two breasts. M. Devergie[2] has found by examination with the microscope, that the milk of women differs not only in respect to the size of the globules, but to the number of these,—a high or low amount of globules indicating richness or poorness of the milk generally. Of 100 nurses, 17 had the large globuled variety; 22 the small globuled; and 61 the medium size.

The quantity of milk secreted is not always in proportion to the bulk of the mammæ: a female whose bosom is of middle size often secretes more than one in whom it is much more developed;—the greater size being usually owing to the larger quantity of adipous tissue surrounding the mammary gland, which tissue is nowise concerned in the function. The ordinary quantity of milk that can be squeezed from either breast at any one time, and which must consequently have been contained in its tubes and reservoirs, is about two fluidounces. The secretion usually continues until the period when the organs of mastication of the infant have acquired the necessary developement for the digestion of solid food; and it generally ceases during the second year. For a great part, or the whole of this time, the catamenia are suspended; and if both the secretions,—mammary and menstrual, go on together, the former is usually impoverished, and in small quantity. This, at least, is the general opinion. Some, however, think, that no general rule can be established on the subject; and that the condition of the child's health ought to be the only guide in regard to weaning, after the recurrence

[1] Animal Chemistry, Amer. edit., p. 51, Cambridge, 1842.
[2] Mémoires de l'Académie Royale de Médecine, tom. x. Paris, 1843.

of the catamenia. M. Gendrin would on no account permit a woman to continue nursing after they had returned. The subject has been investigated by M. Raciborski,[1] who laid the results before the *Académie Royale de Médecine*, of Paris, in May, 1843. His inferences are,—that, contrary to generally received opinion, the milk of nurses who menstruate during suckling does not differ sensibly, in physical, chemical, or microscopic characters, from that of nurses whose catamenia are suspended;—that the only difference, which can be detected between the two kinds of milk, is, that in most cases the milk of menstruating nurses contains less cream during the menstrual periods than in the intervals, which accounts for the bluish appearance occasionally presented by such milk;—and that a nurse should never be rejected merely because she menstruates.

Whilst lactation continues, the female is less likely to conceive; hence the importance,—were there not even more weighty reasons,—of the mother's suckling her own child in order to prevent the too rapid succession of children. From observations made at the Manchester Lying-in Hospital on one hundred and sixty married women, Mr. Roberton[2] concludes, that in seven out of eight women, who suckle for as long a period as the working classes in England are in the habit of doing—about fifteen and a half months on the average—there will be an interval of fifteen months between parturition and the commencement of the subsequent pregnancy; and that, in a majority of instances, when suckling is prolonged to even nineteen or twenty months, pregnancy does not take place till after weaning. In a work on the law of population and subsistence, Dr. Loudon[3] lays down the theory, that the laws of nature require lactation to be prolonged for three years; and he expresses an opinion, that the antagonism between the uterus and mammæ is so great as usually to prevent conception in women who have infants at the breast. The opinion does not agree, however, with the facts arrived at by Dr. Roberton, and it is still more opposed to those of Dr. Laycock,[4] who states that 135 married women afforded 209 pregnancies during 766 lactations, or 1 pregnancy in 3·66 lactations, or 27 per cent. The 209 pregnancies occurred in 76 females:—that is, 56 per cent. became pregnant whilst suckling; but in 30 of these, pregnancy occurred only once. If the thirty be deducted, there remain 46 or 33·9 per cent., or nearly 1 in 3, who became pregnant on more than one occasion whilst suckling; and 19 of these, or 1 in 7 had always—after their first pregnancy—conceived whilst suckling.

When menstruation recurs during suckling, it is an evidence that the womb has again the organic activity which befits it for impregnation.

[1] Dublin Medical Press, Aug., 2d, 1843.
[2] Edinb. Med. and Surg. Journal, Jan., 1837.
[3] Solution du Problème de la Population, &c., Paris, 1842; cited by Dr. West, in Brit. and For. Med. Rev., April, 1844, p. 541.
[4] Dublin Medical Press, Oct. 26, 1842.

CHAPTER II.

FŒTAL EXISTENCE.—EMBRYOLOGY.

Whilst the uterine alterations, which have been pointed out in the last chapter, are taking place, the ovum is undergoing a succession of changes, and the new being is passing through the different phases of intra-uterine existence. The history of these, in the early period, is extremely obscure, owing to the difficult nature of the investigation; and on many deeply interesting points we are compelled to remain in doubt. It is a subject, which has engaged the attention of physiologists of all ages; but it is chiefly to those of more modern times—as Hunter, Cuvier, Dutrochet, Pander, Rolando, Sir Everard Home and Mr. Bauer, Prévost and Dumas, Von Baer, Kuhlemann, Döllinger, Oken, Purkinje, Rathke, C. F. Wolff, Breschet, Burdach, Reichert, Carus, Krause, Seiler, Bojanus, Meckel, E. H. Weber, Bernhardt, Valentin, Coste, Owen, Sharpey, Velpeau, Flourens, Allen Thomson, T. W. Jones, Bischoff, Schwann and Schleiden, J. Müller, Pouchet, Wagner and Martin Barry,—the last two of whom received, about the same time, medals for their researches, the former from the Institute of France; the latter from the Royal Society of London—that we are indebted for our more accurate and precise information.

1. ANATOMY AND HISTOLOGY OF THE FŒTUS.

a. *Fœtal Developement.*

As the developement of the mammalia greatly resembles that of birds, the histogeny of the impregnated ovum, at the earliest periods, was, until of late years, chiefly studied in the latter; and there can be no doubt—as Wagner[1] has remarked,—that carefully conducted researches on the ovum of these animals are much better calculated to throw light on the developement of the human embryo than any amount of necessarily unconnected observations of human ova aborted at an early period; and, in the majority of cases perhaps, morbid. "Unquestionably," observes Valentin,[2] "the class of birds is the centre around which all observations on developement arrange themselves, and this, not so much on account of any grounds intrinsic to this class, as by reason of extrinsic circumstances, which are completely under our control. In no other class of animals do we possess the same facilities of procuring embryos in the various stages of their progress. Nowhere can we multiply and repeat our inquiries to the same extent as here. It was on this account that Fabricius ab Aquapendente began his investigations with the brooded egg, and that Harvey and Malpighi followed in the same course. It was on the egg that Wolff made his im-

[1] Elements of Physiology, by R. Willis, p. 80, Lond., 1841.
[2] Handbuch der Entwickelungsgeschichte, Vorrede s. x.

portant discoveries in regard to the formation of the intestinal canal, of the blood, of the extremities, and of the kidneys; and it was by the study of the embryo of the common fowl, that Döllinger and his school, in our own day, were enabled to give a permanent foundation to the history of developement as a science. The bird must, therefore, and on these grounds, be made the starting point for all future inquiries, the norma and basis to which insulated facts in the developement of mammalia and man must be referred." It has been well remarked, too, by Wagner,[1] that whoever would work out a knowledge of the developement of animals generally for himself must begin with the study of the chick, were it only for the reason, that we possess the best descriptive works upon this portion of the subject. The early processes of developement are, indeed, the same in all animals. "The embryos of different animals resemble each other more strongly in proportion as we examine them at an early period. We have already stated, that during almost the whole period of embryonic life, the young fish and the young frog scarcely differ at all; so it is also with the young snake, compared with the embryo bird. The embryo of the crab, again, is scarcely to be distinguished from that of the insect; and if we go still farther back in the history of developement, we come to a period when no appreciable difference whatever is to be discovered between the embryos of the various departments. The embryo of the snail, when the germ begins to show itself, is nearly the same as that of a fish or a crab. All that can be predicted at this period is, that the germ, which is unfolding itself, will become an animal: the class and group are not yet indicated."[2]

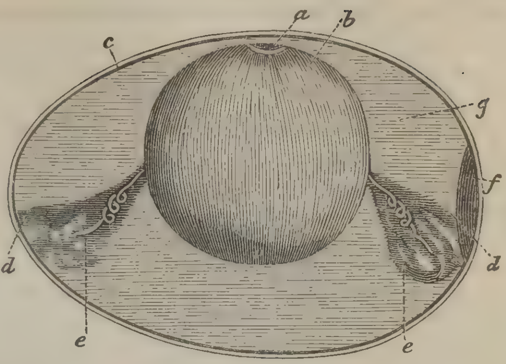
The egg of a bird—of a hen, for example—consists of two descriptions of parts,—the one comprising those that are but little concerned in the developement of the new being;—the other those that remain after the chick is hatched,—as the shell and the shell membrane which lines it; and those that undergo changes along with the chick, and cooperate in its formation, as the white, the yolk, and the *cicatricula*, *macula*, *tread* or *gelatinous molecule* as it was formerly termed—which includes the *germinal vesicle* or *Purkinjean vesicle*, and the *germinal* or *germ spot* of later observers.

When the ovule quits the ovary, it consists only of the yolk and its investing membrane:—with the germinal vesicle and germinal spot. (See Figs. 384 and 385.) The yolk serves the same purpose for the animal as the amylaceous and oily matter in the seed serves for the plant. It is the nutriment on which the embryo subsists, until it is capable of obtaining it in another manner. On this yolk is the cicatricula, consisting, as has been said, of a nucleated cell, of which the germinal spot is the *nucleus*,—the germinal vesicle the *cell*. In its passage through the oviduct, the ovule receives the albumen or white of egg, the purpose of which is to serve as nutriment; for it is gradually taken up as the yolk is exhausted. This is deposited upon the surface of the ovule; and from the bloodvessels of the lining of the oviduct

[1] Op. cit.
[2] Agassiz and Gould, Principles of Zoology, part 1, page 123, Boston, 1848.

are thrown out the materials that go to the formation of the *shell membrane — membrana testæ*—as well as of the shell itself. This membrane separates into two layers at the larger end of the egg; and, enclosed between them, is the *folliculus aëris* or *air chamber*, containing a bubble of air, and inservient to the respiration of the embryo. The yolk floats within the albumen, and being the lighter of the two tends to rise towards the upper portion; but is retained nearly in the same place by two cords formed of very viscid albumen, which connect the yolk bag with the lining membrane at the two ends of the shell, and are called *chalazæ* or *poles*.

Fig. 412.



Section of Bird's Egg.

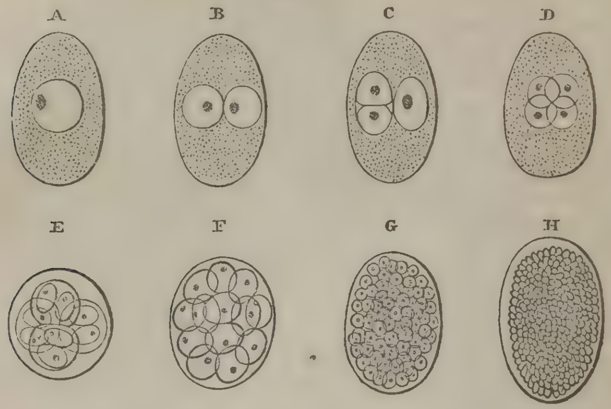
a. Cicatricula. *b*. Yolk. *c*. Shell membrane. *d*. Attachment of chalazæ. *e*. Chalazæ. *f*. Air-chamber. *g*. Albumen.

The ovum of the mammalia is strikingly analogous to this. When it leaves the ovary, it consists of the *yolk* or *vitellus*, contained in its yolk-bag, and of the germinal vesicle and germinal spot. At times, however, the germinal vesicle disappears before the ovum leaves the ovary; but at others not until it has entered the Fallopian tube or oviduct; and it is only in its passage through the tube, that it receives,—by means of nucleated cells, thrown out from the lining membrane,—the *chorion*, which is thus analogous to the albumen or white, the shell membrane and shell of the bird.

In tracing the early developement of the ova of mammiferous animals, difficulty has existed; and hence attention has been chiefly paid to the lower animals, in which there is every reason to believe that similar phenomena occur. Prior to impregnation, the germinal vesicle and germinal spot are visible in the ovum; but after fecundation, the germinal vesicle disappears, and in its place is seen a nucleated cell (Fig. 413, A), which appears to be a new formation. A process of duplication now takes place, which is depicted by Kölliker and Bagge, as seen by them in the ova of certain parasitic worms, in which it presents itself in its least complex form; and, owing to the transparency of the objects, can be the more readily traced. The nucleus of the first nucleated embryonic cell is divided, and each new nucleus is soon succeeded by two other cells; these by four; and these again by eight, as illustrated in Fig. 413; this duplication continuing, and the cells being progressively smaller, until ultimately a large mass of cells results, which assumes the form of the embryo. (H, Fig. 413.) Along with these changes, the yolk is experiencing considerable modification. In some entozoa, as in those described in Fig. 413, the embryonic portion is embedded in the interior of the yolk, and as the cells

multiply, they draw into them the nutrient matter that surrounds them, until the whole yolk is absorbed, and the original yolk-bag is filled

Fig. 413.



Duplication of Cells.

A, B, C, D. Successive stages of the ovum of ascaris dentata, showing duplication of cells. E, F, G, H. Ovum of cucullanus elegans, showing the advance of the process. (From Kölliker.)

with a mulberry-like mass of cells; but the more common method is for each of the cells formed by the cleaving of the embryonic vesicle to draw around it a certain portion of the yolk as in Fig. 414.[1]

The same kind of metamorphosis, or cleaving of the yolk, occurs in the mammalia; prior to this, however, certain changes have been ob-

Fig. 414.

Cleaving of the Yolk after Fecundation.

A, B, C. Ovum of ascaris nigrovenosa. (From Kölliker.) D and E. That of ascaris acuminata. (From Bagge.)

served by Bischoff.[2] The cells of the membrana granulosa, that are in immediate contact with the ovum, undergo a peculiar change when it is about to leave the ovary—becoming club-shaped, their pointed extremities being attached to the zona pellucida so as to give to the ovum a stellate appearance; but when the ovum has entered the Fallopian tube, they lose this shape and become round; and in this form they continue, in the bitch, to invest the ovum throughout the whole tract of the Fallopian tube, and are no longer seen when it reaches the uterus; but in the rabbit they disappear at the commencement of the

[1] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation, and Developement, p. 66, London, 1848.

[2] Entwickelungsgeschichte des Hunde-eies, p. 41; and Baly and Kirkes, p. 64.

tube, and it is observed that the yolk no longer completely fills the zona pellucida; a clear space being left between them.

In its progress through the tube, besides the reception of the chorion as an investing membrane, no change of structure is seen in the ovum,

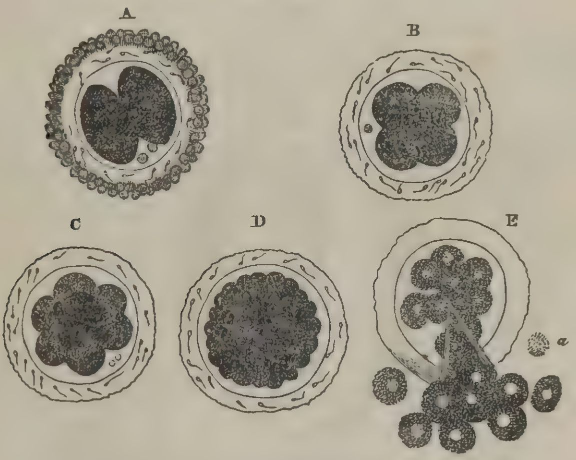
Fig. 415.

Membrana Granulosa of an Ovum from the Ovary.

A. An ovarian ovum from a bitch in heat, exhibiting the elongated form and stellate arrangement of the cells of the discus proligerus or membrana granulosa around the zona pellucida. B. The same ovum after the removal of most of the club-shaped cells. (Bischoff.)

excepting that the zona pellucida is thicker; but Bischoff[1] observed in the rabbit, that regular energetic rotatory movements were executed by the yolk within the zona pellucida, which he ascribed to the motions of vibratile cilia on the surface of the yolk.

Fig. 416.



Ova from the Fallopian Tube and Uterus.

A. Ovum of a bitch, from the Fallopian tube, half an inch from its opening into the uterus, showing the zona pellucida with adherent spermatozoids, the yolk divided into its first two segments, and two small granules or vesicles contained with the yolk in the cavity of the zona. B. Ovum of a bitch from the lower extremity of the Fallopian tube: the cells of the tunica granulosa have disappeared: the yolk is divided into four segments. C. Ovum of bitch from the lower extremity of the Fallopian tube, in a later stage of the division of the yolk. D. An ovum from the uterus: it is larger, the zona thicker, and the segments of the yolk are very numerous. E. Ovum from the lower extremity of the Fallopian tube burst by compression: the segments of the yolk have partly escaped, and in each of them a bright spot or vesicle is visible. (Bischoff.)

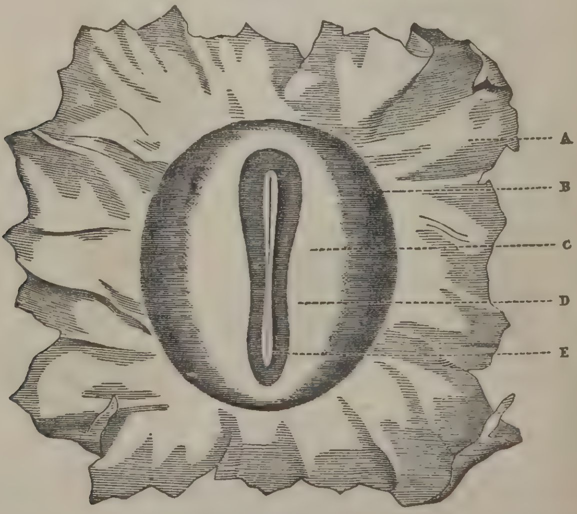
It is in the second half of the Fallopian tube, that the cleaving of

[1] Müller's Archiv., s. 14, Jahrgang, 1841; and Elements of Physiology, by Baly, p. 1564, Lond., 1838.

the yolk begins; which is now resolved into a number of smaller spheroidal masses, under the same process of duplication that has been witnessed in the entozoa. Each mass contains a transparent vesicle like an oil globule, in which no nucleus has been detected; yet the vesicles would appear to possess plastic powers like the primordial embryonic vesicle from which they descended.

At the time when the mammalian ovum has reached the uterus, the cleaving process has ceased; but soon afterwards important changes take place. Each of the globular segments of the yolk becomes surrounded by a membrane, which forms it into a cell; and when the peripheral cells, which are first formed, are fully developed, they arrange themselves at the surface of the yolk into a kind of membrane, and assume a pentagonal or hexagonal shape from pressing on each other, so as to resemble pavement epithelium. As the globular masses of the interior are gradually formed into cells, they pass to the surface; increase the thickness of the membrane formed by the peripheral layer of cells, whilst the central part of the yolk is filled only with a clear fluid. By this means, the yolk is converted into a kind of secondary vesicle, situated within the zona pellucida, which Bischoff calls the *blastodermic vesicle,—vesicula blastodermica*, the *blastoderma* or *germinal membrane*, because in it is first observed the *germ* or earliest trace of the new being. Soon after its formation, the membrane presents, at some point on its surface, an opaque roundish spot, caused by an ac-

Fig. 417.



Portion of the Germinal Membrane of a Bitch's Ovum, with the Area Pellucida and Rudiments of the Embryo. Magnified ten diameters.

A. Germinal membrane. B. Area vasculosa. C. Area pellucida. D. Laminæ dorsales. E. Primitive groove, bounded laterally by the pale pellucid substance of which the central nervous system is composed. (After Bischoff.)

cumulation of cells and nuclei of less transparency than elsewhere; and it is here—in the *area germinativa*, as it is called—that the embryo

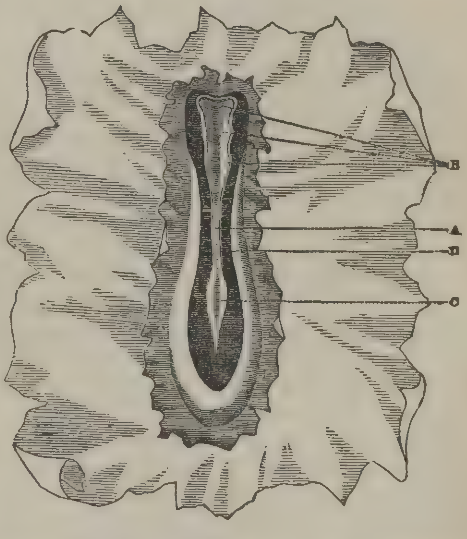
first appears. The germinal membrane increases in thickness by the formation of new cells, and is divisible into two layers, which are, at first, most distinct at the area germinativa; but the separation soon extends, and affects nearly the whole germinal membrane. The outer layer of these is called the *serous layer* and also the *animal layer*, because from it are formed the organs of animal life:—the nervous system, bones, muscles, &c.; whilst the latter or inner layer is called the *mucous* or *vegetative layer*, because from it are formed the vegetative or nutritive organs.

The area germinativa has, at first, a rounded form, which it soon loses, becoming first oval, and then pyriform; and whilst this change is taking place, a clear space—*area pellucida*—is seen in its centre; this is bounded externally by a more opaque circle, which subsequently becomes the *area* or *area vasculosa*, so called because bloodvessels are there first developed. In the formation of both these areas, the two layers participate.

The first appearance of the embryo is seen in the serous layer and in the centre of the area pellucida. It consists of a shallow groove—*primitive groove, trace or streak*—having on each side two oval masses—*laminæ dorsales*—the form of which changes with that of the area pellucida; being, at first, oval, then pyriform, and at length shaped like a guitar. At the same time, they become more and more raised, and the tops of the elevations approach each other, until they ultimately convert the groove into a tube, which is the seat of the future great central organs of the nervous system—the brain and spinal marrow. At the same time, on a line parallel with the primitive groove, a row of cells is seen, which are the rudiments of the future vertebral column;—this is termed the *chorda dorsalis*.

Whilst the dorsal laminæ are approaching to close the primitive groove, thickened prolongations of the serous layer are given off from the lower margin of each. These—called ventral or visceral laminæ, *laminæ ventrales* seu *viscerales*—at first, proceed on the same plane with the germinal membrane, but they gradually bend down-

Fig. 418.

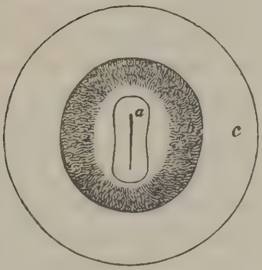


Portion of the Germinal Membrane, with Rudiments of the Embryo from the Ovum of a Bitch.

The primitive groove, A, is not yet closed, and at its upper or cephalic end presents three dilatations, B, which correspond to the three divisions or vesicles of the brain. At its lower extremity the groove presents a lancet-shaped dilatation (sinus rhomboidalis) C. The margins of the groove consist of clear pellucid nerve-substance. Along the bottom of the groove is observed a faint streak, which is probably the chorda dorsalis. D. Vertebral plates. (After Bischoff.)

ward and inwards, towards the cavity of the yolk, where they unite, and form the anterior wall of the trunk; and whilst these changes are supervening, an accumulation of cells is taking place between the serous and the mucous layer of the germinal membrane, which arrange themselves into a distinct layer—the *vascular*—in which the first vessels of the embryo are developed.

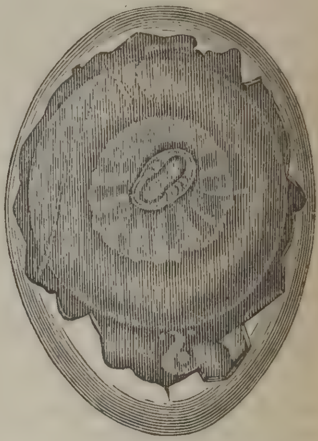
Fig. 419.



Vascular Area in the Chick thirty-six hours after Incubation. (After Wagner.)

a. Yolk. *b*. Fiddle-shaped pellucid area, in the middle of which is the embryo. In the vascular area, *c*, *c*, the insulæ sanguinis or blood islets begin to appear.

Fig. 420.



Egg thirty-six hours after Incubation. (Sir E. Home.)

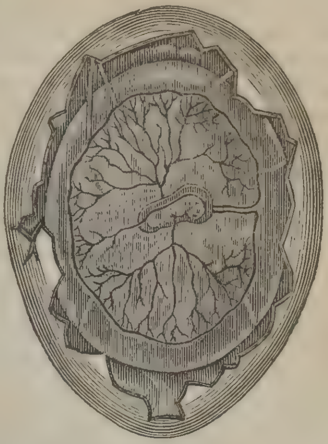
Such are the phenomena presented by the embryo chick; but, according to Dr. Martin Barry,[1] there does not occur in the mammiferous ovum any such phenomenon as the splitting of a germinal membrane into the "so-called *serous*, *vascular*, and *mucous* laminæ. Nor is there any structure entitled to be denominated a *germinal membrane;* for it is not a previously existing membrane, which originates the germ; but it is the previously existing germ, which, by means of a hollow process, originates the structure having the appearance of a membrane." This we have no doubt is the fact as regards the relation of the germ to the germinal membrane, yet the phenomena may present themselves in the manner above described.

When the vascular layer is formed, blood dots or islets—*insulæ sanguinis*—appear at the circumference of the vascular area, which gradually unite so as to form vessels filled with blood, which have a retiform appearance and circular shape;—hence the name *circulus venosus* and *vena* seu *sinus terminalis* given to the *figura venosa*. The vascular area gradually extends itself over the whole surface of the membrane that contains the yolk; as is well seen in the accompanying figures of the chick at different stages of incubation.

[1] Philosophical Transactions for 1838, 1839 and 1840, and Wagner's Elements of Physiology, p. 153 (note), London, 1841.

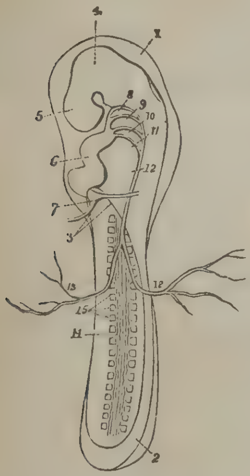
From this network in the area vasculosa, vessels extend into the area pellucida, and join the rudimental heart, which has, at first, the form of a long slightly curved tube, prolonged inferiorly into two venous trunks, and superiorly into three or more aortic arches on each side. These arches unite beneath the vertebral column to form the aorta (Fig. 422). In the primitive state of the circulation, the descending aorta divides into a right and a left branch (Fig. 423) which pass to the germinal membrane, and are termed *arteriæ omphalo-mesentericæ*, where they ramify until they reach the *circulus venosus*, which—as has been seen—surrounds the area vasculosa; from this, the blood is conveyed back by the *venæ*

Fig. 421.



Egg opened three days after Incubation. (Sir E. Home.)

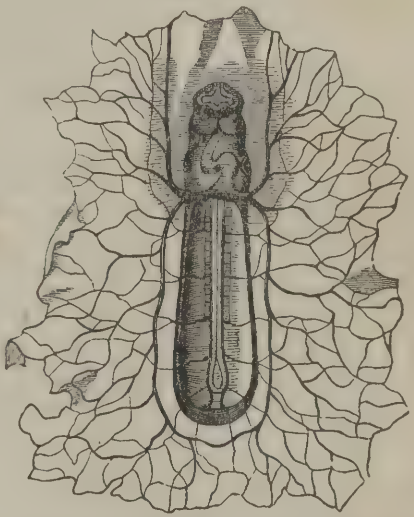
Fig. 422.



Embryo of the Chick at the commencement of the third day, as seen from the abdominal aspect. (After Wagner.)

4. Prominence of the corpora quadrigemina or optic lobes of the brain. 5. The anterior cerebral mass or hemispheres. 6. The heart. 7. Entrance of the great venous trunks in the atrium cordis or auricle. 8, 9, 10 and 11. The four aortic arches. 12. The descending aorta. 13. The arteries of the germinal membrane. 14 The dorsal lamina, rendered slightly wavy by the action of water. 15. The rudiments of the vertebræ.

Fig. 423.



Embryo from a Bitch at the 23d or 24th day. Magnified ten diameters.

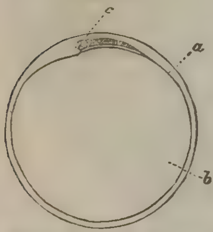
It shows the net-work of bloodvessels in the vascular lamina of the germinal membrane and the trunks of the omphalo-mesenteric veins entering the lower part of the S-shaped heart. The first part of the aorta is also seen. (After Bischoff.)

omphalo-mesentericæ, which issue from the area vasculosa at points corresponding to the anterior and posterior extremities of the embryo (Fig.

423). The sinus terminalis ultimately disappears, and the whole yolk-sac becomes covered with bloodvessels. The same plastic material which formed the different bloodvessels is concerned in the formation of the blood corpuscles; and the essential use of the bloodvessels themselves is, doubtless, to absorb the nutritious matter of the yolk, and convey it to the embryo for histogenic purposes.

At a very early period, the incipient embryo lies, as it does subsequently, with its ventral surface on the yolk sac; and soon, in the mammalia, a constriction takes place in the fold of the germinal membrane in which the parietes of the abdomen are formed; and from this time the yolk sac becomes the *vesicula umbilicalis* or umbilical vesicle. The constricted portion, which remains open for a time, is the *vitelline* or *omphalo-mesenteric duct*, *ductus vitellarius*, *ductus vitello-intestinalis* seu *apophysis*, and the omphalo-mesenteric vessels are still perceptible. Through them, indeed, as at an earlier period, the vitelline matter is conveyed to the embryo. It is affirmed, however, that the vessels are not in immediate contact with the yolk,—a layer of nucleated vitelline cells intervening, which communicate a yellow colour to the vessels beneath, and hence Haller called those vessels *vasa lutea*. It would not seem, however, that cell agency is necessary in this case, for adipous matter readily enters the vessels by imbibition.

Fig. 424.



Plan of early Uterine Ovum. (Wagner.)

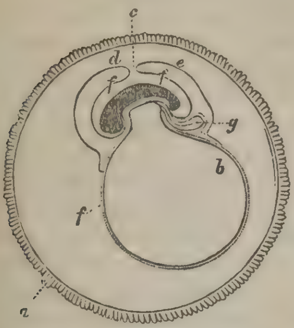
Within the external ring, or zona pellucida, are the serous lamina, *a*; the yolk, *b*; the incipient embryo, *c*.

The walls of the umbilical vesicle or yolk sac are formed of the several layers of the germinal membrane, the mucous and vascular layers of which become much developed; and its vessels—the omphalo-mesenteric, consisting of an artery and two veins—communicate with the abdomen at the umbilicus by the vitelline duct, which, again, communicates with the cavity of the rudimental intestine of the embryo which had been pinched off from the yolk bag; and it was at one time supposed that the nutrient matter of the yolk passed at once through the duct into the rudimental digestive cavity; but it is now generally believed that it is taken up by the vessels in the manner already described.

Whilst the umbilical vesicle is experiencing these developements, another vesicle is seen to project gradually from the caudal extremity of the embryo, which is termed the *allantois* or *allantoid vesicle;* and has been supposed by some histologists to be an offset, as it were, from the intestinal canal: but, according to Bischoff, it is certainly not so in the mammalia, in which it never attains any great size; but in birds it extends itself around the whole of the yolk sac, between it and the shell membrane. The figures on the next page exhibit it at different stages in the egg of the hen; and in the human ovum. As the allantois is developed, its parietes become very vascular, and contain the ramifications of the subsequent umbilical arteries and umbilical vein. Wherever it is met with, it would appear to be a temporary organ of respiration; destined to bring the vessels of the embryo chick in rela-

tion with the external air; and in the mammiferous animal to convey the vessels of the embryo to and from the chorion. As the visceral

Fig. 425.



The Amnion in process of formation, by the arching over of the Serous Lamina.

a. The chorion. *b*. The yolk bag, surrounded by serous and vascular laminæ. *c*. The embryo. *d*, *e*, and *f*. External and internal folds of the serous layer, forming the amnion. *g*. Incipient allantois. (Wagner.)

Fig. 426.

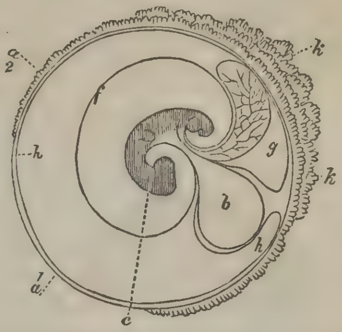
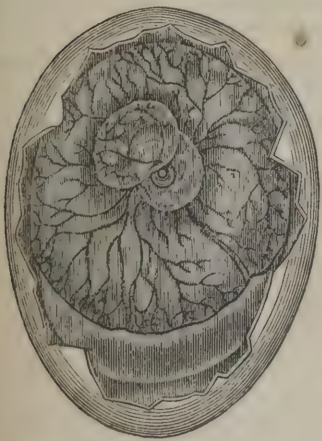


Diagram representing a Human Ovum in the second month. (Wagner.)

a, 1. Smooth portion of chorion. *a*, 2. Villous portion of chorion. *k*, *k*. Elongated villi beginning to collect into placenta. *b*. Yolk sac, or umbilical vesicle. *c*. Embryo. *f*. Amnion (inner layer). *g*. Allantois. *h*. Outer layer of amnion, coalescing with chorion.

laminæ close in the abdominal cavity, the allantois is divided at the umbilicus into two portions; the larger proceeding with the umbilical

Fig. 427.



Egg five days after Incubation. (Sir E. Home.)

Fig. 428.

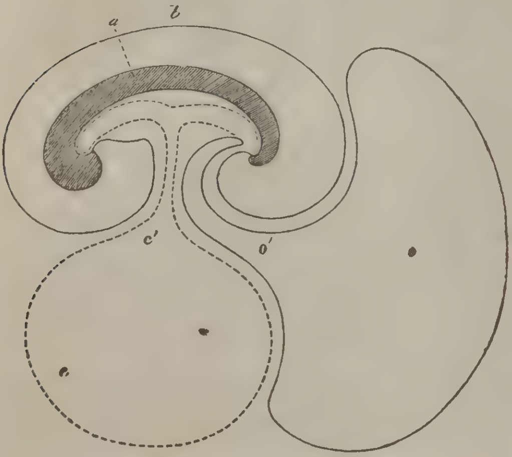
Egg ten days after Incubation. (Sir E. Home.)

vessels to the chorion,—the smaller being retained in the abdomen, and converted into the urinary bladder. The two portions are connected by the *urachus*.

But whilst the umbilical vesicle is undergoing its incipient formation,

by the constriction of that portion of the yolk sac which is in relation with the future umbilicus of the embryo, an important change is taking place in the serous layer of the germinal membrane, the cephalic, caudal and lateral edges of which rise up in two folds, and extend over the body of the embryo from its abdominal towards its dorsal aspect, where they at length meet, and enclose the embryo in a double envelope, one layer of which—the inner—forms the sac of the *amnion;* the other lines the internal surface of the chorion.

Fig. 429.



The Umbilical Vesicle, Allantois, &c.

a. Represents the dorsal structures of the embryo. *b*. The amnion. *c*. The yolk-sac or umbilical vesicle. *c'*. The vitelline duct or pedicle of the umbilical vesicle. *o*. The allantois; and *o'*. The urachus.

Its mode of developement is seen in Figs. 425, 426 and 429.

The amnion is continuous with the integument of the embryo; and the part at which the reflections take place to form it is the *umbilicus;* this is well illustrated in the marginal figure. When the ovum has reached the interior of the uterus it is surrounded by the chorion, which it received in its passage along the Fallopian tube; the villi or fœtal processes on its outer surface come in relation with the enlarged tubular glands of the uterus, and thus the new being derives its early intra-uterine nutriment. Gradually, however, bloodvessels are developed in the villi, which form a junction with those of the allantois—the umbilical vessels; and in this way an indirect vascular communication is established with the uterus, which is concentrated in the part corresponding to the placenta. The mode in which this connection is formed will be described when the dependencies of the fœtus and its physiology are more intimately investigated.

Fig. 430.

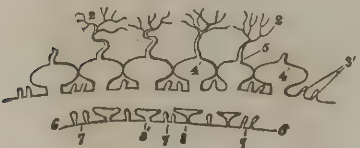


Diagram of part of the Decidua and Ovum separated, to show their mutual relation. (From Dr. Sharpey.)

2, 3, 4, 5. As in the former figure. 6. Chorion. 7. Villi. 8, 8. Fœtal processes of the chorion.

From the difficulty of appreciating the exact age of any ovum or its contained embryo, it is impracticable to assign precise weights or measurements, or, indeed, any special developement to the different periods of intra-uterine existence. The discordance amongst observers is, indeed, extreme; and the following observations can only be regarded as approximations.

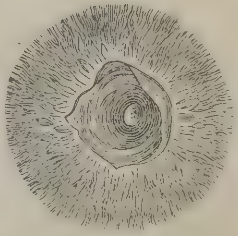
The human ovum does not generally reach the uterus until about ten or twelve days after conception, or after its discharge from the ovary. Reference has already been made to the disputed case by Sir Everard Home, in which, on the seventh or eighth day after conception, the future situations of the brain and spinal marrow were said to have been recognizable by a powerful instrument.[1] On the thirteenth or fourteenth day, according to M. Maygrier, it is perceptible in the uterus, and of about the size of a pea, containing a turbid fluid, in the midst of which an opaque point is suspended. Fig. 431 represents an ovum, which is figured by M. Velpeau, and could not have been more than fourteen days old, unless the midwife, who gave it him, and who was herself the subject of the miscarriage, deceived him; and she appeared to have had no reason for so doing. Good descriptions and representations of the human ovum within the first month from conception are, however, as Wagner[2] has remarked, very rare; and many of the accounts appertain to diseased ova, or to monstrous or distorted embryos thrown off by abortion. Its *weight* at this period, has been valued at about a grain;—*length* one-twelfth of an inch.

Fig. 431.

Ovum fourteen days old.

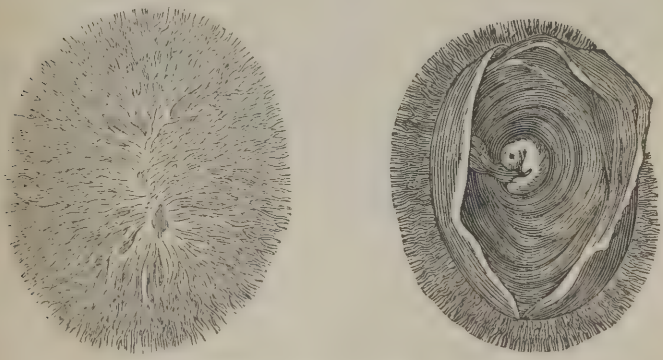
On the twenty-first day, the embryo appears under the shape of a large ant, according to Aristotle; of a grain of lettuce; a grain of barley, according to Burton; of the malleus of the ear, according to Baudelocque;—or is one-tenth of an inch long, according to Pockels. At this period, its different parts have a little more consistence; and those that have afterwards to form bone assume the cartilaginous condition. On the

Fig. 432.



Ovum and Embryo fifteen days old. (Maygrier.)

Fig. 433.



Ovum and Embryo twenty-one days old. (Maygrier.)

[1] Dr. Myddleton Michel, of South Carolina, has described a very early human ovum observed by him; and referred to various others recorded by different observers, in the American Journal of the Medical Sciences for Oct. 1847, p. 330.

[2] Elements of Physiology, translated by R. Willis, p. 161, Lond., 1841.

thirtieth day, some feeble signs of the principal organs and of the situation of the upper limbs are visible;—*length* four or five lines.

About the forty-fifth day, the shape of the child is determinate; and it now, in the language of some anatomists, ceases to be *embryo*, and becomes *fœtus*. According to others, it is not entitled to the latter name until after the beginning of the fourth month.

Fig. 434.

Fœtus at forty-five days.

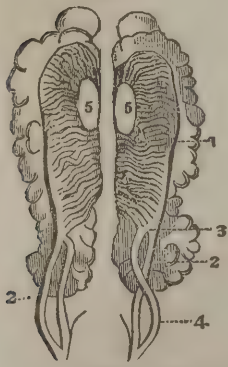
Fig. 435.

Fœtus at two months.

The limbs resemble tubercles, or the shoots of vegetables; the body lengthens, but preserves its oval shape,—the head bearing a considerable proportion to the rest of the body. The base of the trunk is pointed and elongated. Blackish points, or lines, indicate the presence of the eyes, mouth, and nose; and similar parallel points correspond to the situation of the vertebræ. *Length* ten lines.

In the second month, most of the parts exist. The black points, which represented the eyes, enlarge in every dimension; the eyelids are sketched, and are extremely transparent; the nose begins to stand out; the mouth increases, and becomes open; the brain is soft and pulpy, and the heart is largely developed. Prior to this period—very early indeed—substances or bodies are perceptible, which were first described, as existing in the fowl, by Wolff,[1] and in the mammalia by Oken,[2] and which have been called by the Germans, after their discoverers, Wolffische oder Okensche Körper ("bodies of Wolff or Oken"). According to J. Müller, they disappear in man very early, so that but slight remains of them are perceptible after the ninth or tenth week of pregnancy. They cover the region of the kidneys and renal capsules, which are formed afterwards, and are presumed to be organs of urinary secretion during the first periods of fœtal existence. The fingers and toes are now distinct. In the third month, the eyelids are more developed and firmly closed. A small hole is perceptible in the pavilion of the ear. The alæ nasi are distinguishable. The lips are very distinct, and approximate, so that the mouth is closed. The genital organs of both sexes undergo an extraordinary increase during this month. The penis is long; the scrotum empty, frequently containing a little water. The vulva is apparent,

Fig. 436.



Corpora Wolffiana, with Kidney and Testes, from Embryo of Birds.

1. Kidney. 2, 2. Ureters. 3. Corpus Wolffianum. 4. Its excretory duct. 5, 5. Testicles. At the summit are seen the supra-renal capsules.

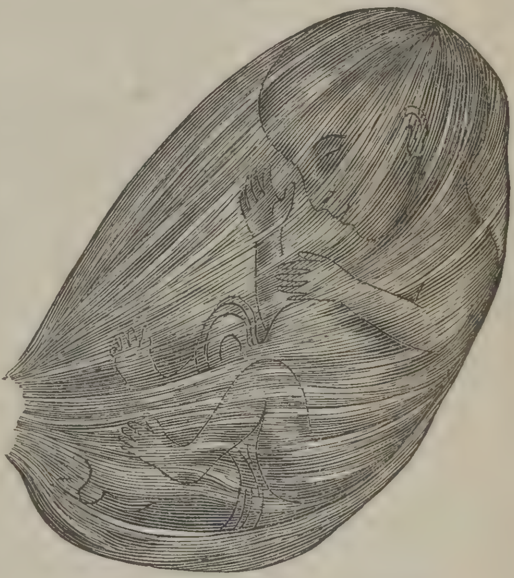
[1] Theoria Generationis, Hal., 1759.

[2] Oken und Kieser, Beiträge zur Vergleichend. Zoologie, Anatomie und Physiologie, H. i. p. 74, Bamberg und Wurzburg, 1806; and Rathke, in Weber's Hildebrandt's Handbuch der Anatom., iv. 440.

and the clitoris prominent. The brain, although still pulpy, is considerably developed, as well as the spinal marrow. The heart beats forcibly. The lungs are insignificant; the liver very large, but soft and pulpy, and appears to secrete scarcely any bile. The upper and lower limbs are developed. *Weight*, two and a half ounces; *length*, three and a half inches.

During the fourth month, all the parts acquire great developement aud character, except perhaps the head and liver, which increase less in proportion than other parts. The brain and spinal marrow acquire greater consistence; the muscular system, which began to be observable in the preceding month, is now distinct; and slight, almost imperceptible, movements begin to manifest themselves. The *length* of the fœtus is, at the end of one hundred and twenty days, five or six inches; the *weight*, four or five ounces. During the fifth month, the developement of every part goes on; but a distinction is manifest amongst them. The muscular system is well marked, and the movements of the fœtus unequivocal. The head is still very large, compared with the rest of the body, and is covered with small silvery hairs. The eyelids are glued together. *Length*, seven to nine inches; *weight*, six or eight ounces. If the fœtus be born at the end of five months, it may live for a few minutes.

Fig. 437.



Fœtus at three months, in its membranes.

In the sixth month, the derma begins to be distinguished from the epidermis. The skin is delicate, smooth, and of a purple colour; especially on the face, lips, ears, palms of the hands and soles of the feet. It seems plaited, owing to the absence of fat in the subcutaneous areolar tissue. The scrotum is small, and of a vivid red hue. The vulva is prominent, and its lips are separated by the projection of the clitoris. The nails appear, and towards the termination of the month are somewhat solid. Should the fœtus be born now, it is sufficiently developed to breathe and cry; but it generally dies in a short time. *Length*, at six months, ten or twelve inches. *Weight*, under two pounds.

During the seventh month all the parts are better proportioned. The head is directed towards the orifice of the uterus, and can be felt

by the finger passed into the vagina, but it is still very movable. The eyelids begin to separate, and the membrane, which previously closed the pupil—*membrana pupillaris*—begins to disappear. The fat is more abundant, so that the form is more rotund. The skin is redder; its sebaceous follicles—which secrete a white, cheesy substance, *vernix caseosa*, that covers it—are formed; and the testicles are in progress to the scrotum. The vernix has been recently analyzed by Dr. John Davy,[1] and found to consist of

Epithelium (epidermis) plates,	13·25
Olein,	5·75
Margarin,	3·13
Water,	77·37

and in the very minute quantity of ashes that remained, there were traces of phosphate of lime and sulphur. It is, consequently, an excretory secretion from the skin. The *length*, at seven months, is fourteen inches; *weight*, under three pounds. In the eighth month, the fœtus increases proportionably more in breadth than in length. All its parts are firmer and more formed. The nails exist; and the child is now certainly *viable* or capable of supporting an independent existence. The testicles descend into the scrotum; the bones of the skull, ribs, and limbs are more or less completely ossified. *Length*, sixteen inches; *weight*, four pounds and upwards.

At the full period of nine months, the organs have acquired the developement necessary for the continued existence of the infant. *Length*, eighteen or twenty inches; *weight*, six or seven pounds. According to Dr. Granville, its *length* is twenty-two inches; *weight* from five to eight pounds. Dr. Dewees[2] says the result of his experience, in this country, makes the average weight about seven pounds. He has met with two ascertained cases of fifteen pounds, and many that he believed to be of equal weight. Dr. Moore, of New York, had several cases, where the weight was twelve pounds; and a case occurred in that city in 1821, of a fœtus, born dead, which weighed sixteen and a half pounds. Dr. Traill[3] once weighed a child at the moment of birth: it weighed 14 pounds; Mr. Park, of Liverpool, found one weigh 15 pounds; and a case has been recorded by Mr. J. D. Owens, in which a still-born child measured 24 inches in length, and weighed 17 pounds 12 ounces.[4] Dr. Storer,[5] of Boston, has published the following results of observations. Of 30 children, 14 females weighed 112 pounds, or averaged 8 pounds each; and 16 males $145\frac{1}{4}$ pounds, or $8\frac{1}{2}$ pounds each. The largest child seen by Dr. Storer was a male, which weighed 13 pounds: the next in weight was $12\frac{1}{2}$ pounds. One weighed 11, one $10\frac{1}{2}$, and two 10 pounds each. The average weight of 836 children, recorded by Dr. Metcalf[6] of Mendon, Massachusetts, was eight

[1] Medico-Chirurgical Transactions, xxvii. p. 189, Lond., 1844.
[2] Compendious System of Midwifery, 8th edit., Philad., 1836.
[3] Outlines of a Course of Medical Jurisprudence, 2d edit., p. 16, Edinb., 1840, or American edition with notes by the author of this work, p. 27, Philad., 1841.
[4] London Lancet, Dec. 22, 1838.
[5] New England Quarterly Journal of Medicine and Surgery, July, 1842.
[6] American Journal of the Medical Sciences, Oct. 1847, p. 314.

pounds, five ounces, and a fraction. The males—429 in number—weighed eight pounds ten ounces each; the females—407 in number—eight pounds.

Dr. Clarke[1] gives the absolute and relative weight of 60 of each sex, as observed at the Dublin Hospital:—60 males weighed 442 lbs.; average 7 lbs., 5 oz., 2 dr. 60 females weighed 404¼ lbs.; average 6 lbs., 11 oz., 2 dr. Average difference 9 oz.

In the Edinburgh Lying-in Hospital, 50 male and 50 female children, born during the latter months of 1842, and the earlier part of 1843, were weighed by Dr. Simpson's assistant, Dr. Johnstone.[2] 50 males weighed 383 lbs., 11 oz., 4 dr.; average 7 lbs., 9 oz., 1 dr. 50 females weighed 342 lbs., 12 oz., 4 dr.; average 6 lbs., 12 oz. Average difference about 10 oz.

The lengths of these were:—50 males, total length, 1020½ inches, average 20 inches, 5 lines. 50 females, total length, 990½ inches; average 19 inches, 10 lines. Average difference 7 lines, or upwards of half an inch.

Where there are twins in utero, the weight of each is usually less than in a uniparous case; but their united weight is greater. M. Dugès, of Paris, found in 444 twins the average weight to be four pounds, and the extreme weights three, and eight pounds. At times, however, they are very large. Dr. P. G. Bertolet, of Oley, Pennsylvania,[3] describes a twin case in which one child weighed nine pounds and a half,—the other, eleven and a quarter pounds,—the united weights being twenty pounds and three-quarters.

The whole of these estimates—as before remarked—give no more than an approximation to the general truth. The facts will be found to vary greatly in individual cases; which accounts for the great discordance in the statements of different observers. This is strongly exemplified in the following table, containing the estimates of the length and weight of the fœtus at different periods of intra-uterine existence, as deduced by Dr. Beck[4] from various observers, and as given by M. Maygrier[5] on his own authority, and by Dr. Granville[6] as the averages of minute and accurate observations made by Autenrieth, Sömmering, Bichat, Pockels, Carus, &c., confirmed by his own observations of several early ova, and of many fœtuses examined in the course of seventeen years' obstetrical practice. It is proper to remark, that the Paris pound, *poids de marc*, of sixteen ounces, contains 9216 Paris grains; whilst the avoirdupois contains only 8532·5 Paris grains; and that the Paris inch is 1·065977 English inch.

[1] Philosophical Transactions, 1786.

[2] Edinburgh Medical and Surgical Journal, Oct. 1844; see, also, Dr. Simpson's Report of the Edinburgh Royal Maternity Hospital, in Monthly Journal and Retrospect of the Medical Sciences, Nov. 1848, p. 332.

[3] Medical Examiner, for Aug. 1848, p. 472.

[4] Medical Jurisprudence, 6th edit. i. 276, Philad., 1838.

[5] Nouvelles Demonstrations d'Accouchemens, Paris, 1822–26.

[6] Graphic Illustrations of Abortion, &c., p. xi., Lond., 1834.

	Length.			Weight.		
	Beck.	Maygrier.	Granville.	Beck.	Maygrier.	Granville.
At 30 days,	3 to 5 lines	10 to 12 lines			9 or 10 grains	
2 months,	2 inches	4 inches	1 inch	2 ounces	5 drachms	20 grains
3 do.	3½ do.	6 do.	3 inches	2 or 3 do.	2½ ounces	1½ ounce
4 do.	5 to 6 do.	8 do.		4 or 5 do.	7 or 8 do.	
5 do.	7 to 9 do.	10 do.		9 or 10 do.	16 do.	
6 do.	9 to 12 do.	12 do.	9 do.	1 to 2 pounds	2 pounds	1 pound
7 do.	12 to 14 do.	14 do.	12 do.	2 to 3 do.	3 do.	2 to 4 pounds
8 do.	16 do.	16 do.	17 do.	3 to 4 do.	4 do.	4 to 5 do.

The difficulty must necessarily be great in making any accurate estimate during the early periods of fœtal existence; and the changes in the after months are liable to considerable fluctuation. M. Chaussier affirms, that after the fifth month, the fœtus increases an inch every fifteen days, and M. Maygrier adopts his estimate. The former gentleman has published a table of the dimensions of the fœtus at the full period, deduced from an examination of more than fifteen thousand cases. From these we are aided in forming a judgment of the probable age of the fœtus in the latter months of utero-gestation;—a point of interest with the medico-legal inquirer. At the full period, the middle of the body corresponds exactly with the umbilicus, or a very little below it; at eight months, it is three-quarters of an inch, or an inch higher. At seven months, it approaches still nearer the sternum; and at six falls exactly at the lower extremity of that bone; hence, if we were to depend upon these admeasurements, should the middle of the body of the fœtus be found to fall at the lower extremity of the sternum, we might be justified in concluding, that the fœtus is under the seventh month, and consequently not *viable* or rearable.

The following are the results of observations made by Dr. A. S. Taylor, Professor of Medical Jurisprudence and Chemistry at Guy's Hospital, and Dr. Geoghegan, Professor of Medical Jurisprudence to the Royal College of Surgeons in Ireland.

Case.	Whole length.	Attachment of the Umbilical Cord.	
1	18½	A quarter of an inch below the centre.	
2	20	Half an inch	Do.
3	17½	Half an inch nearly	Do.
4	16½	Half an inch	Do.
5	19	Do.	Do.
6	17.	A little below the centre.	
7	18	Exactly at the centre.	
8	17	Do. Do.	
9	20¾	A little below the centre.	
10	19½	Do. Do.	
11	18¾	Exactly at the centre.[1]	

A striking circumstance connected with the developement of the fœtus is the progressive diminution in the proportion of the part of the body above the umbilicus to that below it. At a very early period of fœtal life (see Figs. 434 and 435), the cord is attached near the base of the trunk; but the parts beneath become gradually developed, until its insertion ultimately falls about the middle of the body.

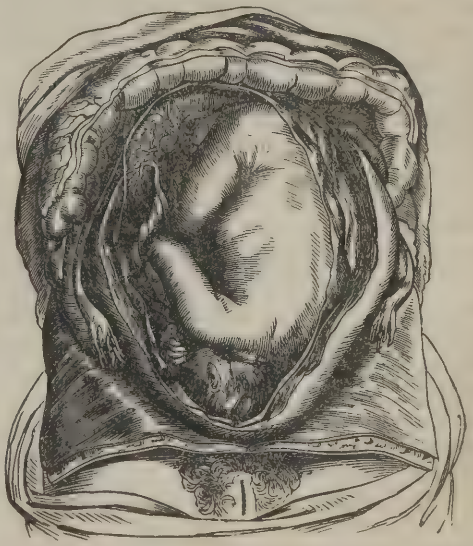
[1] See, on all this subject, A. S. Taylor, Medical Jurisprudence, 2d Amer. edit. by Dr. R. E. Griffith, p. 441, Philad., 1850.

The following table of the length and weight (French), and central point of the fœtus at different ages is given by M. Lepelletier.[1] It still farther exhibits the discordance alluded to above.

Month.	Length.	Weight.	Central point.
1	5 to 6 lines	9 to 15 grains	at the junction of the head and trunk.
2	18 to 20 lines	6 to 8 drachms	at the upper part of the sternum.
3	2 to 3 inches	2 to 3 ounces	at the upper extremity of the xiphoid cartilage.
4	5 to 6 inches	10 to 16 ounces	at the middle of the xiphoid cartilage.
5	7 to 9 inches	1 to 2 pounds	at the lower extremity of the xiphoid cartilage.
6	9 to 12 inches	2 to 3 pounds	several lines below the xiphoid cartilage.
7	12 to 15 inches	3 to 4 pounds	equidistant between the cartilage and the umbilicus.
8	15 to 18 inches	4 to 6 pounds	an inch above the umbilicus.
9	16 to 20 inches	6 to 8 pounds	at the umbilicus.
	Extremes.	*Extremes.*	
	12 to 15 inches (Millot).	2 to 16 pounds (Voistel).	

The position of the fœtus in utero, and the cause of such position at various periods of utero-gestation, have been topics of some interest. In the early weeks, it seems to be merely suspended by the cord; and it has been conceived, that owing to the weight of the head it is the lowest part. It is difficult, however, to admit this as the cause of the position in such an immense majority of cases, or to fancy, that the nice adaptation of the fœtal position to the parts through which the child has to pass is simply dependent upon such a mechanical cause. Gravity can afford us no explanation of the fact, referred to under Parturition, that the face in 12,120 cases of 12,533, has been found turned to the right sacro-iliac synchondrosis, and the occiput to the left acetabulum; and in the 63 of these cases in which the face was turned forwards, and in the 198 breech

Fig. 438.



Full period of Utero-Gestation.

[1] Physiologie Médicale et Philosophique, iv. 451, Paris, 1833.

presentations, are we to presume, that this was owing to greater weight in these parts that were lowest. Dr. Simpson[1] affirms, that the usual position of the fœtus with the head lowest is not assumed until about the sixth month of intra-uterine life;—that both the assumption and maintenance of this position are vital acts, depending upon the vitality of the child, and ceasing at death; and that the cephalic attitude of the fœtus is the one best adapted to the normal shape of the fully developed uterus. The common position, at the full period, is exhibited in the last illustration. The body is bent forward, the chin resting on the chest; the occiput towards the brim of the pelvis; the arms approximated in front, and one or both lying upon the face; the thighs bent upon the abdomen; the knees separated; the legs crossed, and drawn up, and the feet bent upon the anterior surface of the legs; so that the oval, which it thus forms, has been estimated at about ten inches in the long diameter,—the head, at the full period, resting on the neck, and even on the mouth of the womb, and the breech corresponding to the fundus of the organ.

It appears then, that from the first moment of a fecundating copulation, the minute matters furnished by the sexes, commingled, commence the work of developing the embryo. For a short time they find in the ovum the necessary nutriment, and subsequently obtain it from the uterus. The mode in which this action of developement is accomplished is as mysterious as the essence of generation itself. When the impregnated ovum is first seen it is as an amorphous, gelatiniform mass, in which no distinct organs are perceptible. In a short time, however, the brain and spinal marrow, and bloodvessels, make their appearance; but it has been a topic of controversy which of these is developed first.

Sir Everard Home,[2]—from his own observations of the chick in ovo, as well as from the microscopic appearances presented by the ovum in the case of the female who died on the seventh or eighth day after impregnation, decides, that the organs first formed bear a resemblance to brain, and that the heart and arteries are produced in consequence of the formation of nervous centres. Malpighi, Brera, Pander, Tiedemann, Prévost and Dumas, Velpeau, Rolando, and Schröder van der Kolk,[3] also assign the priority to the nervous system. Meckel, however, admits no primitive organizing element, but believes,—properly, we think,—that the first rudiments of the fœtus contain the basis of every part. On the other hand, the researches of M. Serres on the mode of developement of the nervous system induce him to be in favour of the earlier appearance of the bloodvessels, and this view seems to be supported by the fact, that if an artery of the brain be wanting, or double, the nervous part to which it is usually distributed is equally wanting, or double. The acephalous fœtus has no carotid or vertebral arteries; and the bicephalous or tricephalous have them double or treble. With these views Dr. Granville[4] accords, and he lays it down as

[1] Monthly Journal of Medical Science, July, 1849.
[2] Lect. on Comp. Anat., iii. 292, and 429.
[3] Observationes Anatom. Pathol. et Pract. Argum., Amstel. 1826; cited in Edinb. Med. and Surg. Journal, for April 1, 1836.
[4] Op. cit.

a law, that the nerves invariably appear after the arteries which they are intended to accompany.

A like discordance of ideas exists regarding the precedence in formation of the heart and the bloodvessels. The blood is clearly formed before the heart. It appears at distinct points, and acquires a motion independently of it. The veins appear to be formed first; and then the heart and arteries. This is the view of perhaps the generality of histologists; but a distinguished Italian observer—Rolando—assigns the precedency to the arteries.

MM. Geoffroy Saint-Hilaire,[1] Meckel,[2] Serres,[3] Tiedemann,[4] and others are of opinion, that the developement of the embryo takes place from the sides towards the median line—from the circumference towards the centre; but M. Velpeau[5] thinks, that the median line is first formed. The spinal marrow is the first portion of the nervous system that appears; and this system, he believes, precedes every other. On all these deeply interesting but most intricate points of organogeny farther researches are demanded.

b. *Fœtal Dependencies.*

These are the parts of the ovum, that form its parietes, attach it to the uterus, connect it with the fœtus, and are inservient to the nutrition and developement of the new being.

They are generally conceived to consist,—*First*, of two membranes, according to common belief, which constitute the parietes of the ovule, and are concentric; the outermost, called *chorion*,—the innermost, filled with a fluid, in which the fœtus is placed, and called *amnion* or *amnios*. By Boer and Granville,[6] a third and outer membrane has been admitted,—the *cortical membrane* or *cortex ovi*. *Secondly*, of a spongy, vascular body, situate without the chorion, covering about one-quarter of the ovule, and connecting it with the uterus—the *placenta*. *Thirdly*, of a cord of vessels, called the *umbilical cord* or *navel string*—extending from the placenta to the fœtus, within which are vessels; and *lastly*, of two vesicles—the *umbilical*, *allantoid*, and some have added a third—the *erythroid*, which are considered to be concerned in fœtal nutrition. As many of these dependencies have already fallen under consideration in certain of their relations, it will not be necessary to say much concerning them here.

1. *Chorion.*—The chorion—which has received various names—is the outermost of the membranes of the ovum. It has been already remarked (p. 523) that this envelope is considered to be received by the ovum as it passes along the Fallopian tube. Some, however, maintain that it is present in the ovum before it leaves the ovary; and it is so represented by Gerlach.[7] Generally, it is presumed to be formed

[1] Philosophie Anatomique, Paris, 1818–22.
[2] Handbuch der Anatomie, Band. i.
[3] Recherches d'Anatomie Transcendante, &c., Paris, 1832.
[4] Anatomie du Cerveau, traduit par Jourdan, Paris, 1823.
[5] Embryologie ou Ovologie Humaine, Paris, 1833.
[6] Graphic Illustrations of Abortion, Lond., 1834.
[7] Handbuch der Allgemeinen und Speciellen Gewebelehre des Menschlichen Körpers, 3te Lieferung, s. 341, Mainz, 1849.

from an albuminoid secretion of nucleated cells from the lining membrane of the Fallopian tube, and perhaps in addition from the zona pellucida, which disappears at this period. About the twelfth day after conception, according to M. Velpeau,[1] it is thick, opaque, resisting, and flocculent at both surfaces. These flocculi, in the part of the ovum that corresponds to the tunica decidua reflexa, aid its adhesion to that membrane; but in the part where the ovum corresponds to the uterus they become developed to constitute the placenta. At its inner surface, the chorion corresponds to the amnion. These two membranes are separated, during the earliest period of fœtal existence, by an albuminous fluid; but at the expiration of three months, the liquid disappears, and they are afterwards in contact. By many anatomists, the chorion is conceived to consist originally of two laminæ; and by Burdach[2] these have been distinguished by different names; the outer lamina being called *exochorion;* the inner, *endochorion.* M. Velpeau denies this; and asserts, that he has never been able to separate them, even by the aid of previous maceration.

As the placenta is formed on the uterine side of the chorion, the membrane is reflected over the fœtal surface of that organ, and is continued over the umbilical cord as far as the umbilicus of the fœtus, where it is confounded with the skin, of which it has consequently appeared to be a dependence. As pregnancy advances, the chorion becomes thinner, and less tenacious and dense, so that at the full period it is merely a thin, transparent, colourless membrane, much more delicate than the amnion. Haller, Blumenbach and Velpeau affirm it to be devoid of vessels; but, according to Wrisberg, it receives some from the umbilical trunks of the fœtus, and, according to others, from the decidua. M. Dutrochet conceives it to be an extension of the fœtal bladder. Its vascularity, according to Dr. Granville, is proved by its diseases, which are chiefly of an inflammatory character, ending in thickening of its texture; and he affirms, that there is a preparation in the collection of Sir Charles Clarke, which shows the vessels of the chorion as evidently as if they were injected.

2. *Amnion.*—The amnion—whose mode of formation has been described before—lines the chorion concentrically. It is filled with a serous fluid, and contains the fœtus. In the first days of fœtal existence, it is thin, transparent, easily lacerable, and somewhat resembling the retina. At first, it adheres to the chorion only by a point, which corresponds to the abdomen of the fœtus,—the other portions of the membranes being separated by the fluid already mentioned, called *false liquor amnii.* Afterwards, the membranes coalesce, and adhere by very delicate areolar filaments; but the adhesion is feeble, except at the placenta and umbilical cord. In the course of gestation, this membrane becomes thicker and tougher; and, at the full period, is more tenacious than the chorion; elastic, semi-transparent, and of a whitish colour. Like the chorion, it covers the fœtal surface of the placenta, envelopes the umbilical cord, passes to the umbilicus of the fœtus, and there commingles with the skin.

[1] Embryologie, Paris, 1833.

[2] Physiologie als Erfahrungswissenschaft, ii. 57.

It has been a question whether the amnion is supplied with bloodvessels. M. Velpeau denies it: Haller and others maintained the affirmative. Haller asserts that he saw a branch of the umbilical artery creeping upon it. The fact of the existence of a fluid within it, which is presumed to be secreted by it, would to a certain extent also favour the affirmative. But, admitting that it is supplied with bloodvessels, a difference has existed in regard to the source whence they proceed; and anatomical investigation has not succeeded in dispelling it. Dr. Monro affirms, that on injecting warm water into the umbilical arteries of the fœtus, the water oozed from the surface of the amnion. Wrisberg asserts, that he noticed the injection stop between the chorion and amnion; whilst M. Chaussier obtained the same results as Monro, by injecting the vessels of the mother.

The amnion contains a serous fluid, the quantity of which is in an inverse ratio to the size of the new being; so that its weight may be several drachms, when that of the fœtus is only a few grains. At first, the *liquor amnii*,—for so it is called,—is transparent; but, at the full period, it has a milky appearance, owing to flocculi of an albuminous substance held in suspension in it. It has a saline taste, a spermatic smell, and is viscid and glutinous to the touch. Vauquelin and Buniva[1] found it contain, water, 98·8; albumen, chloride of sodium, soda, phosphate of lime, and lime, 1·2. That of the cow, according to these gentlemen, contains amniotic acid; but Prout, Dulong, Labillardière and Lassaigne were not able to discover it. Dr. Rees analyzed several specimens. He found its specific gravity to be about 1·007 or 1·008, and its mean composition in two cases at 7½ months, as follows: water, 986·8; albumen (traces of fatty matter), 2·8; salts soluble in water, 3·7; albumen from albuminate of soda, 1·6; salts soluble in alcohol, 3·4; lactic acid, urea, 1·7. Total, 1000. The salts consisted of chloride of sodium, and carbonate of soda, with traces of alkaline sulphate and phosphate. Vogt[2] analyzed it at two different periods of pregnancy, at 3½ months and 6 months, and found the constituents to vary as follows:—

	3½ Months.	6 Months.
Water,	978·45	990·29
Alcoholic extract, consisting of uncertain animal matter and lactate of soda,	3·69	0·34
Chloride of sodium,	5·95	2·40
Albumen (as residuum)	10·79	6·77
Sulphate and phosphate of lime, and loss,	0·14	0·30
	1000·	1000·
Specific gravity,	1·0182	1·0092

No inferences can, however, be drawn from these cases as to the proportion of solid matters at different periods of utero-gestation, inasmuch as the subject of the first case died of an inflammatory disease;

[1] Annales de Chimie, tom. xxxiii.; and Mémoires de la Société Médicale d'Emulation, iii. 229.

[2] Müller's Archiv.; cited in Brit. and For. Med. Review, July, 1838, p. 248.

the other of cachexia. Dr. Prout[1] found sugar of milk in the liquor amnii of the human female; Berzelius detected fluoric acid in it; Scheele, free oxygen;[2] and Lassaigne,[3] in one experiment, a gas resembling atmospheric air; in others, carbonic acid and nitrogen. Professor J. Müller,[4] however, was never able to detect oxygen in it. The chemical history of this substance is, consequently, sufficiently uncertain; nor is its origin placed upon surer grounds;—some physiologists ascribing it to the mother; others to the fœtus,—opinions fluctuating, according to the presumed source of the vessels that supply the amnion with arterial blood. It has even been supposed to be the transpiration of the fœtus, and its urine.

One reply to these views is, that we find it in greater relative proportion when the fœtus is small. Meckel thinks, that it chiefly proceeds from the mother, but that, about the termination of pregnancy, it is furnished in part by the fœtus. The functions, however, to which, as we shall see, it is probably inservient, would almost constrain us to regard it as a secretion from the maternal vessels; and what perhaps favours the idea is the asserted fact, that if a female has been taking rhubarb for some time prior to parturition, the liquor amnii has been found tinged by it.[5] It is interesting, also, to recollect, that, in the experiments of Dr. Blundell, which consisted in obliterating the vulvo-uterine canal in rabbits, and, when they had recovered from the effects of the injury, putting them to the male,—although impregnation did not take place, the womb, as in extra-uterine pregnancy, was developed, and the waters collected in it. The fluid, consequently, must, in these cases, have been secreted from the interior of the uterus. May not the liquor amnii be secreted in this manner throughout the whole of gestation, and pass through the membranes of the ovum by simple imbibition? and may not the fluid secretions of the fœtus, which are discharged into the liquor amnii, traverse the membranes, and enter the system of the mother in the same way?

The quantity of the liquor amnii varies in different individuals, and in the same individual at different pregnancies, from four fluidounces to as many pints. Occasionally, it is to such an amount as to throw obscurity even over the very fact of pregnancy. An instance of the kind, strongly elucidating the necessity of the most careful attention on the part of the practitioner, occurred in the practice of a respectable London practitioner,—a friend of the author. The abdomen of a lady had been for some time enlarging by what was supposed to be abdominal dropsy; fluctuation was evident, yet the case was equivocal. A distinguished accoucheur, and a surgeon of the highest eminence, were called in consultation, and after examination the latter declared, that "it was an Augean stable, which nothing but the trocar could clear out." As the lady, however, was even then complaining of intermittent pain, it was deemed prudent to make an examination *per vaginam*. The

[1] Annals of Philosophy, v. 417.

[2] Dissert. de Liquoris Amnii Arteriæ Asperæ Fœtuum Humanorum Naturâ et Usu, &c., Copenh., 1799.

[3] Archiv. Général. de Méd., ii. 308.

[4] Handbuch der Physiologie, i. 305, Berlin, 1833.

[5] Cazeaux, Traité Théorique et Pratique de l'Art des Accouchements, p. 176, Paris, 1840.

os uteri was found dilated and dilating; and in a few hours after this formidable decision, she was delivered of a healthy child, the gush of liquor amnii being enormous. After its discharge, she was reduced to the natural size, and the *dropsy*, of course, disappeared.

3. *Cortical membrane* or *cortex ovi.* This is, according to Boer and Granville,[1] the membrane that is usually regarded as a uterine production, and denominated *decidua reflexa.* In the view of Boer, it surrounds the ovule when it descends into the uterus, and envelopes the shaggy chorion. This membrane is destined to be absorbed during the first months of utero-gestation, so as to expose the next membrane to the contact of the decidua; with which a connexion takes place in the part where the placenta is to be formed. In that part, Boer and Granville consider, that the cortex ovi is never altogether obliterated, but only made thinner; and in process of time it is converted into a mere pellicle or envelope, which not only serves to divide the filiform vessels of the chorion into groups or cotyledons, in order to form the placenta, but also covers those cotyledons. This Dr. Granville calls *membrana propria.* The cortical membrane is not admitted by physiologists.

4. *Placenta.*—This is a soft, spongy, vascular body, formed at the surface of the chorion, adherent to the uterus, and connected with the fœtus by the umbilical cord. It is not in existence during the early period of the embryo state; but its rudimental formation commences, perhaps, with the arrival of the embryo in the uterus. In the opinion of some, the flocculi, which are at first spread uniformly over the whole external surface of the chorion, gradually congregate from all parts of the surface into one, uniting with vessels proceeding from the uterus, and traversing the decidua, to form the placenta;—the decidua disappearing from the uterine surface of the placenta about the middle of pregnancy, so that the latter comes into immediate contact with the uterus. In the opinion of others, it is formed by the separation of the layers of the chorion, and by the developement of the different vessels that creep between them. M. Velpeau[2] maintains, that the placenta forms only at the part of the ovule which is not covered by the true decidua, and which is immediately in contact with the uterus; and that it results from the developement of the granulations which cover this part of the chorion;—these granulations or villi, according to him, being gangliform organs containing the rudiments of the placental vessels. Others, again, regard it as formed by the growth of the vessels of the uterus into the decidua serotina. An accurate histologist, Professor Goodsir,[3] has investigated this subject, and the following is his account of the incipient formation of the placenta from the elements supplied by the vascular villi of the chorion on the one hand, and the decidua on the other. The vessels of the decidua enlarge, and assume the appearance of sinuses, encroaching on the space formerly occupied by the cellular decidua, in the midst of which the villi of the chorion are embedded. The increase in the caliber of the decidual capillaries proceeds to such an extent, that the villi are finally completely bound up and covered

[1] Graphic Illustrations of Abortion, part iv., Lond., 1835.
[2] Embryologie ou Ovologie Humaine, p. 63.
[3] Anatomical and Pathological Considerations, p. 60, Edinb., 1845.

by the membrane that constitutes the walls of the vessels,—this membrane filling the contour of all the villi, and even passing to a certain extent over the branches and stems of the tufts. Between this membrane or wall of the enlarged decidual vessels, and the internal membrane of the villi, there still remains a layer of the cells of the decidua. From this up to the full period, all that portion of decidua in connexion with the group of enlarged capillaries and vascular tufts of the chorion, and which, according to Mr. Goodsir, may be now called a placenta, is divided into two portions. The first portion of the decidua in connexion with the placenta, or forming a part of it, is situate between that organ and the wall of the uterus. "This," says Mr. Goodsir, "is the only portion of the placental decidua, with which anatomists have been hitherto acquainted, and I shall name it the parietal portion. It has a gelatinous appearance, and consists of rounded or oval cells. Two sets of vessels pass into it from the uterus. The first set includes vessels of large size, which pass through it for the purpose of supplying the placenta with maternal blood for the use of the fœtus. These may be named the maternal functional vessels of the placenta. The second set are capillary vessels, and pass into this portion of the decidua for the purpose of nourishing it. They are the nutritive vessels of the placenta."

The mode in which the placenta is attached to the uterus has been an interesting question with physiologists; and it has been revived, of late years, by Messrs. Lee,[1] Radford,[2] and others. A common opinion has been, that the large venous canals of the uterus are uninterruptedly continuous with those of the placenta. Wharton and Reuss,[3] and a number of others, conceive, that at an early period of pregnancy the part of the uterus in contact with the ovum becomes fungous or spongy, and that the *fungosities*, which constitute the uterine placenta, commingle and unite with those of the chorion so intimately, that laceration necessarily occurs when the placenta is extruded; and M. Dubois goes so far as to consider milk fever as a true traumatic disease, produced by such rupture. The opinion of Messrs. Lee, Radford, Velpeau, and others is, that the maternal vessels do not terminate in the placenta; but that apertures—portions scooped out, as it were,—exist in the parietes of those vessels, which are closed up, according to the two first gentlemen, by the true decidua;—according to M. Velpeau, by a membranule or anorganic pellicle, which he conceives to be thrown out on the fungous surface of the placenta,—or by some valvular arrangement, the nature of which has not been discovered; but these apertures have no connection, in his opinion, with any vascular orifice either in the membrane or placenta. The mode, therefore, in which these authors consider the placenta to be attached to the uterus is, so far as it goes, somewhat unfavourable to the idea generally entertained, that the maternal vessels pour their fluid into the maternal side of the

[1] Philosoph. Trans. for 1832; and Remarks on the Pathology and Treatment of some of the most important Diseases of Women, Lond., 1833.

[2] On the Structure of the Human Placenta, Manchester, 1837.

[3] Novæ quædam Observationes circa Structuram Vasor. in Placent. Human. et peculiarem hujus cum Utero Nexum, Tubing, 1784.

placenta, whence it is taken up by the radicles of the umbilical vein. Whatever blood is exhaled must necessarily pass through the decidua, according to Messrs. Lee and Radford; or through the pellicle, according to M. Velpeau. Subsequently Dr. Lee[1] somewhat modified his views, and expressed the belief, that the circulation in the human ovum, in the third month of gestation, is carried on in the following manner:—The maternal blood is conveyed by the arteries of the uterine decidua into the interstices of the placenta and villi of the chorion. The blood, which has circulated in the placenta, is returned into the veins of the uterus by the oblique openings in the decidua covering the placenta. The blood, which has circulated between the villosities of the chorion, passes through the opening in the decidua reflexa into the cavity between the two deciduous membranes, whence it is taken up by the numerous apertures and canals that exist, according to him, in the uterine decidua; and so passes into the veins of the uterus. Biancini[2] maintains, that a number of flexuous vessels connect the uterus directly with the placenta, which are developed immediately after the period of conception. These utero-placental vessels, he says, are not prolongations of the uterine vessels, but a new production.

Fig. 439.

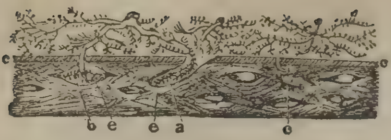
The Extremity of a Villus magnified 200 diameters. (After Weber.)

The loop, 1, is filled with blood; the other loop, 2, is empty; 3 is the margin of the pellucid villus.

The late Dr. John Reid[3] carefully examined this point of anatomy. On cautiously separating the adhering surfaces of the uterus and placenta under water, he satisfied himself, but not without considerable difficulty, of the existence of the utero-placental vessels described by the Hunters. After a portion of the placenta had been detached in this manner, Dr. Reid's attention was attracted towards a number of rounded bands passing between the uterine surface of the placenta and the inner surface of the uterus, several of which could be drawn out in the form of tufts from the uterine sinuses. On slitting up some of the sinuses with the scissors, the tufts could be seen ramifying in their interior. These were ascertained to be prolongations of the fœtal placental vessels, and to protrude into certain of the uterine sinuses, and in those placed next the inner surface of the uterus only. These tufts were surrounded externally by a soft tube, similar to the soft wall of the utero-placental vessels, which passed between the margin of the open mouths of the uterine sinuses and the edges of the orifices in the decidua through which the tufts protruded into the sinuses. On examining the tufts, as they lay in the sinuses, it was evident, that though they were so far loose, and could be floated about, yet they were bound down firmly at various points by reflections of the inner coat of the venous system of

[1] London Med. Gazette, Dec., 1838.
[2] Sul Commercio Sanguigno tra la Madre e il Feto, Pisa, 1833.
[3] Edinburgh Med. and Surg. Journal, Jan. 1841, p. 4.

Fig. 440.

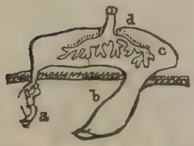


Transverse Section of the Uterus and Placenta.

a and *b*. Uterine sinuses with tufts of fœtal placental vessels prolonged into them. *c*. Curling artery passing through decidua vera. *d*. Decidua vera. *e*. Tufts of placental vessels. (J. Reid.)

the mother upon their outer surface. Dr. Reid farther satisfied himself, that the interior of the placenta is composed of numerous trunks and branches, each including an artery and an accompanying vein, every one of which, he believes, is closely ensheathed in prolongations of the inner coat of the vascular system of the mother, or at least in a membrane continuous with it. According to this idea of the structure of the placenta, the inner coat of the vascular system of the mother is prolonged over each individual tuft, so that when the blood of the mother flows into the placenta through the curling arteries of the uterus, it passes into a large sac formed by the inner coat of the vascular system of the mother, which is intersected in many thousands of different directions by the placental tufts projecting into it like fringes, and pushing its thin wall before them, in the form of sheaths, that closely envelope the trunk and each individual branch composing these tufts. From this sac, the maternal blood is returned by the utero-placental veins without having been extravasated, or without having left the maternal system of vessels. Into this sac in the placenta containing the blood of the mother, the tufts of the placenta hang like the branchial vessels of certain aquatic animals, to which they have a marked analogy. This sac is protected and strengthened on the fœtal surface of the placenta by the chorion, on the uterine surface by the decidua vera, and on the edges or margin by the decidua reflexa.

Fig. 441.



Connexion between the Maternal and Fœtal Vessels.

a. Curling artery. *b*. Uterine vein. *c*. Placenta. *d*. Placental tufts with inner coat of vascular system of the mother enveloping them. (J. Reid.)

In this view, the fœtal and maternal portions are everywhere intimately intermixed with tufts of minute placental vessels, their blunt extremities being found lying immediately under the chorion covering its fœtal surface, as well as towards its uterine surface. The discovery of the prolongations of the fœtal placental vessels into some of the uterine sinuses, Dr. Reid thinks, is principally valuable, as it presents us with a kind of miniature representation of the whole structure of the placenta; and the reason why the placental tufts are not perceptible on the uterine surface of the placenta expelled in an accouchement is, that they are so strongly bound down by the reflection of the inner coat of the uterine sinuses that they are torn across. Professors Alison, Allen Thomson, and J. Y. Simpson inspected the preparations of Dr. Reid, and expressed themselves satisfied, that the placental tufts were prolonged into the uterine sinuses, and that the inner coat of the veins was prolonged upon them. Dr. Sharpey, too, confirms the views of Dr. Reid from his own observation of impregnated uteri; and Dr. Churchill[1]

[1] The Theory and Practice of Midwifery, 2d Amer. edit., by Professor Huston, p. 110, Philad., 1846.

states, that in a visit to Edinburgh, Dr. Reid showed him one of the portions of uterus and placenta on which his investigations were made, and there was no difficulty in demonstrating the tufts dipping into the uterine sinuses. "No doubt," he adds, "farther observations are necessary for the perfect elucidation of the subject; but I certainly think, that as far as our knowledge extends, it is in favour of the opinion adopted by Dr. Reid and the later physiologists." A somewhat similar view to that of Dr. Reid is entertained by Prof. E. H. Weber.[1]

The fœtal placental tufts, when injected, form beautiful preparations.

Since Dr. Reid's observations were made, Professor Goodsir[2] has discovered on the fœtal tufts villi like those of the intestinal canal, and internal cells on the tufts, which he considers to be precisely analogous to those of the intestinal villi, described in the first volume of this work. "Within the internal membrane," he remarks, "and on the external surface of the umbilical capillaries, are cells, which I have named the internal cells of the tuft. When the vessels are engorged, these cells are seen with difficulty. When the vessels are moderately distended, and the internal membrane separated from the external cells by moderate pressure, the cells now under consideration come into view. They are best seen in the spaces left between the internal membrane and the retiring angles formed by the coils or loops of the vessels, and in the vacant spaces formed by these loops. These cells are egg-shaped, highly transparent, and are defined by the instrument with difficulty; but their nuclei are easily perceived. They appear to be filled with a highly transparent refractive matter. This system of cells fills the whole space that intervenes between the internal membrane of the villus and the vessels, and gives to this part of the organ a mottled appearance."

Fig. 442.

Extremity of a Placental Villus.

a. External membrane of the villus, continuous with the lining membrane of the vascular system of the mother. *b.* External cells of the villus, belonging to the placental decidua. *c, c.* Germinal centres of external cells. *d.* The space between the maternal and fœtal portions of the villus. *e.* The internal membrane of the villus, continuous with the external membrane of the chorion. *f.* The internal cells of the villus, belonging to the chorion. *g.* The loop of umbilical vessels. (After Goodsir.)

The function of the external cells of the placental villi is, in Mr. Goodsir's view, to separate from the blood of the mother the matter destined for the blood of the fœtus. "They are, therefore, secreting cells, and are the remains of the secreting mucous membrane of the uterus." The cells within the placental villi—the "internal cells" referred to above—belong to the system of the fœtus. They are the cells of the villi of the chorion, and their function is to absorb "the matter secreted by the agency of the external cells of the villi." The placenta, consequently, in Mr. Goodsir's view, performs not only the function of a lung, but that of an intestinal tube.

In whatsoever manner primarily produced, the placenta is distinguish-

[1] Hildebrandt, Handbuch der Anatomie des Menschen, iv. 496, Braunschweig, 1832.

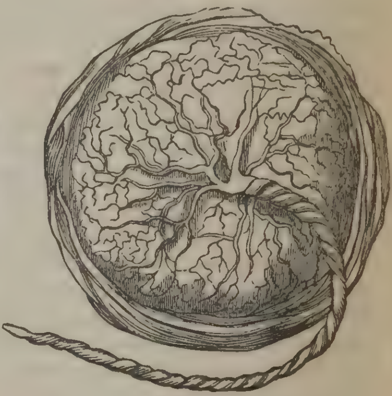
[2] Anatomical and Pathological Observations, Edinburgh, 1845.

able in the second month, at the termination of which it covers two-thirds, or at least, one-half of the ovum: after this, it increases in size, but far less rapidly than the ovum. Prior to the full term, however, it is said to be less heavy, more dense, and less vascular, owing—it has been conceived—to several of the vessels that formed it having become obliterated and converted into hard fibrous filaments; a change, which has been regarded as a sign of maturity in the fœtus, and a prelude to its birth. At the full period, its extent has been estimated at about one-fourth of that of the ovum; its diameter from six to nine inches; circumference twenty-four inches; thickness from an inch to an inch and a half at the centre, but less than this at the circumference; and its weight, with the umbilical cord and membranes, at from twelve to twenty ounces. All this is subject, however, to much variation. Of 325 observed cases in the Edinburgh Royal Maternity Hospital,[1] the average weight was lb. 1, oz. 4, dr. 14[?] Its shape is circular, and the cord is usually inserted into its centre. It may be attached to any part of the uterus,

Fig. 443.

Uterine Surface of the Placenta.

Fig. 444.



Fœtal Surface of the Placenta.

but is usually found towards the fundus. Of its two surfaces, that which corresponds to the uterus is divided into irregularly rounded lobes or *cotyledons*, and is covered by a soft and delicate areolo-vascular membrane, which, by many, is considered to be decidua vera. Wrisberg,[2] Lobstein,[3] and Desormeaux,[4] however, who consider, that the decidua disappears from behind the placenta about the fourth or fifth month, regard it as a new membrane; and Bojanus, believing it to be produced at a later period than the decidua vera, gives it the name of *decidua serotina*.[5] (See Fig. 400, page 485 of this volume.) Mr. Breschet, again, affirms, that two laminæ—*decidua vera* and *decidua reflexa*—are found intervening between the uterus and placenta,[6] whilst M. Velpeau

[1] Monthly Journal and Retrospect of the Medical Sciences, Nov. 1848, p. 332.
[2] Observ. Anat. Obstetric. de Structurâ Ovi et Secundinar. Human., &c., Gotting., 1783.
[3] Essai sur la Nutrition du Fétus, Strasbourg, 1802.
[4] Art. Œuf Humain, in Dict. de Médecine.
[5] Isis, von Oken, für 1821.
[6] Mémoir. de l'Académ. Royal. de Médec., tom. ii. Paris, 1833.

maintains that the true decidua never exists there! The *fœtal* or *umbilical surface* is smooth; polished; covered by chorion and amnion, and exhibits the distribution of the umbilical vessels, and the mode in which the cord is attached to the organ.

The following are the chief anatomical constituents of the placenta, as usually described by anatomists. *First.* Bloodvessels from two sources,—the mother and fœtus. The former proceed from the uterus, and consist of arteries and veins, the arteries of small size but considerable number. The vessels, which proceed from the fœtus, are those contained in the umbilical cord—the umbilical vein, and umbilical arteries. These vessels, after having penetrated the fœtal surface of the placenta, divide in the substance of the organ, so that each lobe and perhaps each ultimate tuft has an arterial and a venous branch, which ramify in it, but do not anastomose with the vessels of other lobes. *Secondly.* White filaments, which are numerous in proportion to the advancement of pregnancy, and seem to be obliterated vessels. *Thirdly.* Intermediate areolar tissue, serving to unite the vessels together, and which has been regarded, by some anatomists, as an extension of the decidua accompanying those vessels. *Lastly.* A quantity of blood contained in the ultimate maternal and fœtal vessels. In addition to these constituents, lymphatic vessels have been presumed to exist in it. Fohmann[1] affirms, that in addition to the bloodvessels, the umbilical cord consists of a plexus of absorbents, which may be readily injected with mercury. This has been done, also, by Dr. Montgomery, of Dublin. The lymphatics of the cord communicate with a network of lymphatics, seated between the placenta and amnion, the termination of which Fohmann could not detect, but, he thinks, they pass to the uterine surface of the placenta. These proceed to the umbilicus of the child, and chiefly unite with the subcutaneous lymphatics of the abdominal parietes; follow the superficial veins; pass under the crural arches; ramify on the iliac glands; and terminate in the thoracic duct. Lobstein and Meckel, however, were never able to detect lymphatics in the cord.

Chaussier and Ribes,[2] and Mr. Cæsar Hawkins[3] describe nerves in the placenta which they refer to the great sympathetic of the fœtus.

The uterine and fœtal portions of the placenta are generally described as quite distinct from each other, during the first two months of fœtal life; but afterwards as constituting one mass. The uterine vessels remain distinct from the fœtal—the uterine arteries and veins communicating freely with each other, as well as the fœtal arteries and veins; but no direct communication exists between the maternal and fœtal vessels. Until of late, almost every obstetrical anatomist adopted the division of the placenta into two parts, constituting—as it were—two distinct placentæ,—the one maternal, the other fœtal. Messrs. Lee, Radford, and others, however, contested this point, and affirmed, with M. Velpeau, that the human placenta is entirely fœtal. If, indeed, the idea of M. Velpeau were true, that a membrane, or as he calls it—"membranule," exists between the placenta and the uterus, it

[1] Sur les Vaisseaux Absorbans du Placenta, &c., Liège, 1832; and Amer. Journ., May, 1835, p. 174.

[2] Journal Universel des Sciences Médicales, i. 233.

[3] Sir E. Home, Lect. on Comp. Anat., v. 185, Lond., 1828.

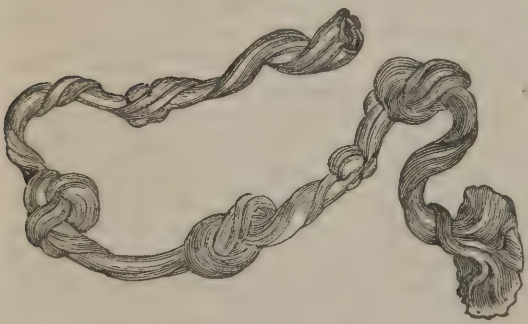
would destroy the idea of any direct adhesion between the placenta and uterus, and make the placenta wholly fœtal. Yet the point—as we have seen—is still contested,—by those especially, who consider that both the maternal and fœtal vessels ramify in the placenta, a view now embraced by the best histologists.

It is generally supposed, that the placenta is most frequently attached to the right side of the uterus, but Nägele[1] found the opposite to be the fact in his examinations. In six hundred cases, which he carefully auscultated, it was met with in two hundred and thirty-eight cases on the left side, and in one hundred and forty-one on the right.

5. *Umbilical cord.*—From the fœtal surface of the placenta a cord of vessels passes, which enters the umbilicus of the fœtus, and has hence received the names *Funis*, *F. umbilicus*, *umbilical cord*, and *navel string*. It forms the medium of communication between the fœtus and placenta. During the first month—Pockels[2] says the first three weeks—of fœtal existence, the cord is not perceptible; the embryo appearing to be in contact, by the anterior part of its body, with the membranes of the ovum. Such, at least, is the description of most anatomists; but M. Velpeau[3] says it is erroneous. The youngest embryo that he dissected had a cord. At from a fortnight to three weeks old, its length is three or four lines; and he thinks his examinations lead him to infer, that at every period of fœtal developement, its length is nearly equal to that of the body, if it do not exceed it a little.

In an embryo a month old, M. Béclard[4] observed vessels creeping, for a certain space, between the membranes of the ovum, from the abdomen of the fœtus to a part of the chorion, where the rudiments of the future placenta were visible. During the fifth week, the cord is straight, short, and very large, owing to its containing a portion of intestinal canal. It presents, also, three or four dilatations, separated by as many contracted portions or necks; but these gradually disappear; the cord lengthens, and becomes smaller, and occasionally it is twisted, knotted, and tuberculated in a strange manner. (Fig. 445.) After the fifth week it contains—besides the duct of the umbilical vesicle—the omphalo-mesenteric vessels, and a portion of the urachus or of the allantoid vesicle

Fig. 445.



Knotted Umbilical Cord.

[1] Die Geburtshülfliche Auscultation, Mainz, 1838; cited in Brit. and For. Med. Rev., Oct. 1839, p. 371.

[2] Neue Beiträge zur Entwickelungsgeschichte des Menschlichen Embryo, in Isis, von Oken, 1825.

[3] Embryologie ou Ovologie Humaine, Paris, 1833.

[4] Embryologie ou Essai Anatomique sur le Fétus Humain, Paris, 1821.

and intestines. At about two months, the digestive canal enters the abdomen: the urachus; the vitelline canal—and the vessels become obliterated, so that, at three months, as at the full period, the cord is composed of three vessels,—the umbilical vein, and two arteries of the same name,—of a peculiar jelly-like substance, and is surrounded, as we have seen, by the amnion and chorion. These are united by an areolar tissue, containing the *jelly of the cord*, or *Jelly of Wharton*, a thick albuminous secretion, which bears some resemblance to jelly, and the quantity of which is very variable. In the fœtus, the areolar tissue is continuous with the sub-peritoneal areolar tissue; and in the placenta, it is considered to accompany the ramifications of the vessels. The length of the cord varies, at the full period, from eight inches to fifty-four. The most common length is eighteen inches.

It has been already remarked, that Chaussier, Ribes, and Hawkins have traced branches of the great sympathetic of the fœtus as far as the placenta; and the same has been done by Durr,[1] Rieck,[2] and others.

6. *Umbilical vesicle.*—This vesicle, called also *vesicula alba* and *intestinal vesicle*, appears to have been first carefully observed by Albinus.[3] Dr. Granville,[4] however, ascribes its discovery to Bojanus,[5] whilst others have assigned it to Diemerbroeck.[6] It was unknown to the ancients; and, amongst the moderns, is not universally admitted to be a physiological condition. Osiander and Döllinger class it amongst imaginary organs; and M. Velpeau remarks, that out of about two hundred vesicles, which he had examined, in fœtuses under three months of developement, he had met with only thirty in which the umbilical vesicle was in a state, that could be called natural. Under such circumstances, it is not easy to understand how he distinguished the natural from the morbid condition. If the existence of the vesicle be a part of the natural process, the majority of vesicles ought to be healthy or natural; yet he pronounces the thirty in the two hundred to be alone properly formed; and, of consequence, one hundred and seventy to be morbid or unnatural. This vesicle is described as a small pyriform, round or spheroidal sac; which, about the fifteenth or twentieth day after fecundation, is of the size of a common pea. It probably acquires its greatest dimensions in the course of the third or fourth week. After a month, M. Velpeau always found it smaller. About the fifth, sixth, or seventh week, it is about the size of a coriander seed. After this, it becomes shriveled, and disappears insensibly. It seems to be situate between the chorion and amnion, and is commonly adherent either to the outer surface of the amnion, or the inner surface of the chorion; but, at times, is situate loosely between them. It is seen in Figs. 400, 425, 426, and 429.

The characters of the *vitelline pedicle*, as M. Velpeau terms it, which attaches the vesicle to the embryo, vary according to the stage of gesta-

[1] Dissert. Sistens Funicul. Umbilic. Nervis Carere, Tubing., 1815.
[2] Utrum Funiculus Umbilicalis Nervis polleat aut careat., Tubing., 1816.
[3] Annotat. Academic., lib. i. p. 74.
[4] Graphic Illustrations of Abortion, p. xii., Lond., 1834.
[5] Meckel's Archiv., iv. s. 34.
[6] Opera, p. 304, Ultraject. 1672.

tion. At the end of the first month, it is not less than two, nor more than six lines long, and about a quarter of a line broad. Where it joins the vesicle, it experiences an infundibuliform expansion. Its continuity with the intestinal canal appears to be undoubted.[1] Up to twenty or thirty days of embryonic life, the pedicle is hollow, and, in two subjects, M. Velpeau was able to press the contained fluid from the vesicle into the abdomen, without lacerating any part. Generally, the canal does not exist longer than the expiration of the fifth week, and the obliteration appears to proceed from the umbilicus towards the vesicle. The parietes of the *vitelline pouch*—as M. Velpeau calls it, from its analogy to the vitelline or yolk-bag of the chick—are strong and resisting; somewhat thick, and difficult to tear.

As the umbilical vesicle of brutes has been admitted to be continuous with the intestinal canal, anatomists have assigned it and its pedicle three coats. Such is the view of M. Dutrochet. M. Velpeau has not been able to detect these in the human fœtus. He admits, however, a serous surface, and a mucous surface. The vesicle—as elsewhere remarked (p. 530)—is supplied with arteries and veins, generally termed *omphalo-mesenteric* or *omphalo-meseraic*, but, by M. Velpeau, *vitello-mesenteric*, or, simply, *vitelline.* The common belief is, that they communicate with the superior mesenteric artery and vein; but M. Velpeau says he has remarked, that they inosculate with one of the branches of the second or third order of those great vessels (*canaux*),—with those, in particular, that are distributed to the cæcum. The fluid, contained in the vesicle, the *vitelline* fluid, was examined in a favourable case for the purpose by M. Velpeau, who found it of a pale yellow colour; opaque; of the consistence of a thickish emulsion; different in every respect from serosity, to which Albinus, Boerhaave,[2] Wrisberg[3] and Lobstein[4] compared it, and from every other fluid in the organism; and he regards it as a nutritive substance—a sort of oil—in a great measure resembling that which constitutes the vitelline fluid of the chick *in ovo.*

7. *Allantoid vesicle* or *allantois.*—This vesicle—called also *membrana farciminalis* and *membrana intestinalis*—has been alternately admitted and denied to be a part of the appendages of the human fœtus, from the earliest periods until the present day. It has been seen by Emmert, Meckel, Pockels, Velpeau, Von Baer, Burdach, and others; is situate between the chorion and amnion, and communicates, in animals, as before shown—with the urinary bladder by a duct called *urachus.* It has been observed in the dog, sheep, cow, in saurian and ophidian reptiles, birds, &c. M. Velpeau[5] was never able to detect any communication with the bladder in the human subject, and he is compelled to have recourse to analogy to infer, that any such communication in reality exists. From all his facts—which are not numerous or striking—he "thinks himself authorized to say," that from the fifth week after conception until the end of pregnancy, the chorion and amnion are separated by a transparent, colourless, or slightly greenish-yellow layer. This layer, instead of being a simple serosity, is lamellated after the

[1] Purkinje, art. Ei, in. op. cit. x. 157.
[2] Haller, Elementa Physiol., viii. 208.
[3] Descript. Anat. Embryonis, Gotting., 1764.
[4] Op. cit., p. 42.
[5] Embryologie ou Ovologie Humaine, Paris, 1833.

manner of the vitreous humour of the eye. It diminishes in thickness in proportion to the developement of the other membranes. The quantity of fluid, which its meshes enclose, is, on the contrary, in an inverse ratio with the progress of gestation. It becomes gradually thinner and is ultimately formed into a homogeneous and pulpy layer, by being transformed into a simple gelatinous or mucous covering (*enduit*), which wholly disappears in many cases before the period of accouchement. Between the *reticulated body*, as M. Velpeau terms it, and the allantoid of oviparous animals, he thinks, there is the greatest analogy. Yet the fluid of the allantoid is very different from the urine, which is supposed, by some, to exist in the allantoid of animals. This fluid, we shall find, has been considered inservient to the nutrition of the new being, but, after all, it must be admitted, that our ideas regarding the vesicle, in man, are far from being determinate, for admitting—as elsewhere remarked—that it conveys the bloodvessels between the embryo and the chorion; the precise uses of its vesicular character and contents remain to be explained.

8. *Erythroid vesicle.*—This vesicle was first described by Dr. Pockels, of Brunswick, as existing in the human subject. It had been before observed in the mammalia. According to Pockels,[1] it is pyriform; and much longer than the umbilical vesicle, although of the same breadth. M. Velpeau, however, asserts, that he has never been able to meet with it; and he is disposed to think, that none of the embryos, depicted by Pockels, and by Seiler,[2] were in the natural state. Such, too, is the opinion of Weber,[3] and by the later embryologists the vesicle is not noticed.

According to most obstetrical physiologists, when pregnancy is multiple, the ova in the uterus are generally distinct, but contiguous to each other. By others, it has been affirmed, that two or more children may be contained in the same ovum, but this appears to require confirmation. The placenta of each child, in such multiple cases, may be distinct; or the different placentæ, having vascular communications with each other, may be united into one. At other times, in twin cases, but one placenta exists. This gives origin to two cords, and at others to one only, which afterwards bifurcates, and proceeds to both fœtuses. M. Maygrier,[4] however, and others[5] affirm unconditionally, that there is always a placenta for each fœtus; but that it is not uncommon, in double pregnancies, to find the two placentæ united at their margins; the circulation of each fœtus being distinct, although the vessels may anastomose. This was the fact in a case of quadruple pregnancy, communicated by M. Capuron to the *Académie Royale de Médecine*, Jan. 10th, 1837.

c. *Fœtal Peculiarities.*

The head of the fœtus is large in proportion to the rest of the body,

[1] Isis, von Oken, p. 1342, 1825.
[2] Das Ei und Die Gebärmutter des Menschen, u. s. w., p. 24, Dresd., 1832.
[3] Hildebrandt, Handbuch der Anatomie, iv. 518, Braunsch., 1832.
[4] Nouvelles Demonstrations d'Accouchemens, Paris, 1822–26.
[5] Churchill, on the Theory and Practice of Midwifery, 3d Amer. edit., by Dr. Huston, p. 409, Phila., 1848.

and the bones of the skull are united by membrane; the sagittal suture extends down to the nose, so as to divide the frontal bone into two portions; and where this suture unites with the coronal, a quadrangular space is left, filled up by membrane, called *anterior fontanelle* or *bregma*. Where the posterior extremity of the sagittal suture joins the lambdoidal, a triangular space of a similar kind is left, called *posterior fontanelle* or *posterior bregma*. It is important for the obstetrical practitioner to bear in mind the shape of these spaces, as they indicate to him whether the anterior or posterior part of the head is the presenting part. The pupil of the eye, in a very young fœtus, is entirely closed by a membrane, called *membrana pupillaris*, which arises from the inner margin of the iris, and continues there till the seventh month, when it gradually vanishes by absorption. It is a vascular substance, and, like the iris, to which it is attached, separates the two chambers of the eye from each other. Wachendorff[1] first described it in 1738: and both he and Wrisberg detected vessels in it. Its vascularity was denied by Bichat, but it has been demonstrated by J. Cloquet.[2] The membrane is manifestly connected with the process of formation of the delicate organ to which it is attached; and according to Blumenbach,[3] it keeps the iris expanded, during the rapid increase of the eyeball.

In the upper part of the thorax of the fœtus, a large gland, or rather glandiform ganglion exists, called *thymus*, and by Joseph Frank, *corpus incomprehensibile*. It is situate in the superior mediastinum, and lies over the top of the pericardium and arch of the aorta. It has two long cornua above, and two broad lobes below. Its appearance is glandular, and colour variable. In the progress of age it diminishes, so that in the adult it is wasted, and in old age can scarcely be discovered amongst the areolar tissue. Krause[4] states, that he has found it in almost all individuals between twenty and thirty years of age, and often larger than in young children. The common idea is, that its greatest bulk is attained during the latter period of embryonic life; and that it must, consequently, exercise its chief functional activity during fœtal existence, and have some reference to the peculiarities of fœtal life. The observations of Krause do not sanction this idea; and the same may be said of those of Haugsted, who found not merely the absolute, but the relative size of the gland undergo a great increase after birth. Thus, whilst the weight of a dog's thymus at birth may range up to ten grains, it may subsequently increase with such rapidity, that after five months it may weigh nearly four hundred,—a proportional increase of forty times; whilst the weight of the entire animal has increased only twelve or sixteen times. Mr. Simon,[5] from his researches, agrees fully with Haugsted, and infers, that "the thymus can with no more propriety be referred to the needs and uses of fœtal life than the mammæ of the female can be considered subserv-

[1] Commerc. Litterar. Noric., 1740; and Valentin, art. Fœtus, Encycl. Wörterb. u. s. w. xii. 376.

[2] Mémoir sur la Membrane Pupillaire, Paris, 1817.

[3] Institut. Physiolog., § 262.

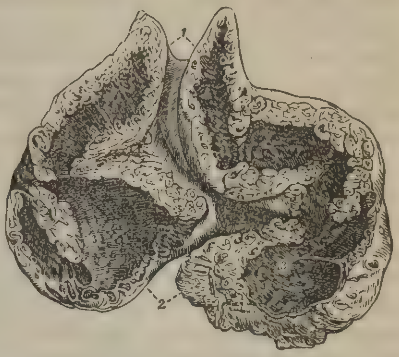
[4] Müller's Archiv., Heft 1, 1837.

[5] A Physiological Essay on the Thymus Gland, Lond., 1845.

ient to the period of utero-gestation." The absolute increase of the gland appears to cease usually at about the age of two years.

The gland is surrounded by a thin, areolar capsule, which sends prolongations into its interior, and divides it into lobules of unequal size, in which several vesicles are distinguishable, filled with a milky fluid, the actual and ultimate nature of which is said to be expressed by the formula for protein. It is, therefore, highly nutrient. Sir Astley Cooper[1] states, that the lobules may be drawn out and separated from each other in the manner of a string of beads, when their enveloping capsule has been removed. The ordinary weight of the thymus has been estimated at half an ounce; but this is probably above the average. Dr. Roberts,[2] of New York, found the average weight, in the full-grown fœtus, to be 229 grains. The thymic arteries proceed from the inferior thyroid, internal mammary, bronchial, mediastinal, &c. The nerves proceed from the pneumogastric, diaphragmatic, and inferior cervical ganglia. It has no excretory duct; and is one of the most obscure in its physiology of any organ of the body, although, like the lymphatic glands, it is probably connected with lymphosis and the function of nutrition. By Mr. Hewson,[3] it was regarded as an appendage to the lymphatic glands for the more perfectly and expeditiously forming the central particles of the blood in the fœtus, and in the early part of life.

Fig. 446.



Section of Thymus Gland at the Eighth Month.

1. Cervical portions of gland; independence of two lateral glands is well marked. 2. Secretory cells seen upon cut surface of section; these are observed in all parts of section. 3, 3. Pores or openings of secretory cells and pouches; they are seen covering whole internal surface of great central cavity or reservoir. Continuity of reservoir in lower or thoracic portion of gland with cervical portion, is seen in the figure. (Sir Astley Cooper.)

The fluid of the thymus has the appearance of chyle or cream, and contains a large number of corpuscles, which are smaller than the blood corpuscles, globular and oval in form; irregular in outline; variable in size; and provided with a small central nucleus.[4] These have been long regarded as identical with the chyle and lymph corpuscles. On treating the sliced thymus with ether, M. Renaud[5] found, that a considerable quantity of oleaginous matter was obtained from it; hence there is great resemblance between its composition, and that of chyle and milk.

[1] The Anatomy of the Thymus Gland, Amer. edit. p. 24, Philad., 1825.

[2] Amer. Journ. of the Med. Sciences, Aug. 1837, Nov. 1838, and Oct. 1841; New York Journ. of Med. and Surg., Jan. 1840; and New York Med. Gaz., July 21, 1841. Also, Dr. C. Lee, in Amer. Journ. of the Med. Sciences, Jan. 1842, p. 138.

[3] Works, Sydenham Society's edit., p. 280, Lond., 1846.

[4] E. Wilson, System of Human Anatomy, 2d Amer. edit., p. 586, Philad., 1844.

[5] London and Edinburgh Monthly Journal of Medical Science, March, 1843.

According to Mr. Simon,[1] in hibernating animals, in which the organ exists through life, as each successive period of hibernation approaches, the thymus gradually enlarges, and becomes loaded with fat, which accumulates in it, and in fat glands connected with it, in even larger proportion than it does in the adipous tissue; and, accordingly, it has been inferred, that it may serve for the storing up of materials to be reabsorbed during the hibernating period, which may maintain at that time the respiration and temperature of the body; or, to employ the language of Mr. Simon—"the gland fulfils its use as a sinking fund of nourishment in the service of respiration;"—and a similar view appears to be embraced by Professor Ecker of Basle.[2]

The *thyroid gland*, which has been described in another place, and whose functions are equally obscure, is also largely developed in the fœtus; as well as the *supra-renal capsules.*

The *lungs*, not having received air in respiration, are collapsed and dense, of a dark colour, like liver, and do not fill the cavity of the chest. Their specific gravity is greater than that of water, and consequently they sink in that fluid. On cutting into them, no air is emitted, and no hemorrhage follows. The *absolute* weight is, however, less; no more blood being sent to them than is required for their nutrition; whilst, after respiration is established, the whole of the blood passes through them: the vessels are consequently filled with blood; enlarged, and the organs themselves increased in absolute weight. Ploucquet asserts, from experiments, that the mean weight of the lungs of a full-grown fœtus, which never respired, is to that of the whole body as 1 to 70: whilst that of lungs in which respiration has been established is as 1 to 35, or doubled. These numbers cannot, however, be considered to afford a satisfactory average,—the exceptions being numerous; but they exhibit that, as might be expected, the absolute weight of the lungs is less, prior to the establishment of respiration. Careful and extended observations have satisfactorily shown, that although an increase in weight is generally found after respiration has been completely established, it is by no means the case when the inspirations have been feeble, as they often are for some hours and days after birth; and, on the other hand, it is not unusual to find, in infants that have not breathed, lungs as heavy as in the average of those that have. The subject is one of great interest as connected with infanticide; and has been well treated by Dr. J. B. Beck, in Beck's *Elements of Medical Jurisprudence*,—one of the best medico-legal works in existence—as well as by Devergie, Guy, Taylor and others.

It is, however, in the circulatory system of the fœtus, that we meet with the most striking peculiarities. The heart is proportionably larger and more conical than in the adult. The *valve of Eustachius*—at the left side of the mouth of the inferior vena cava, where that vessel joins the sinus venosus—is larger than at an after period, and is supposed to direct the principal part of the blood of the ascending cava directly through the opening that exists between the right and left

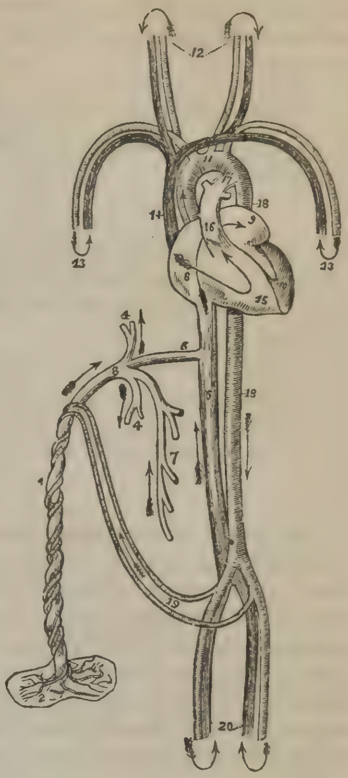
[1] A Physiological Essay on the Thymus Gland, London, 1845.

[2] Art. Blutgefässdrüsen, in Wagner's Handwörterbuch der Physiologie, 23ste Lieferung, s. 127, Leipzig, 1849.

auricle. This opening, which is called *foramen ovale* or *foramen of Botal*, is in the septum between the auricles, and is nearly equal in size to the mouth of the inferior cava. It is situate obliquely; and has a membrane, forming a distinct valve, and somewhat of a crescentic shape, which allows part of the blood of the right auricle to pass through the opening into the left auricle, but prevents its return.

The pulmonary artery, instead of bifurcating as in the adult, divides into three branches;—the right and left going to the lungs of the corresponding side, whilst the middle branch,—to which the name *ductus arteriosus* is given,—opens directly into the descending aorta; so that a great part of the blood of the pulmonary artery passes directly into that vessel. From the internal iliac arteries, two considerable vessels arise, called *umbilical arteries.* These mount by the sides of the bladder, on the outside of the peritoneum, and perforate the umbilicus in their progress to the umbilical cord and placenta. The *umbilical vein*, which is also a constituent of the cord, and conveys the blood from the placenta to the fœtus, arises from the substance of the placenta by a multitude of radicles, which unite together to form it. Its size is considerable. It enters the umbilicus, passes towards the inferior surface of the liver, and joins the left branch of the vena porta hepatica. Here a vessel exists called *ductus venosus*, which opens into the vena cava inferior, or joins the left vena hepatica where that vein enters the cava. A part only of the blood of the umbilical vein goes directly to the vena cava; the remainder is distributed to the right and left lobes of the liver, especially to the latter.

Fig. 447.



Circulatory Organs of the Fœtus.

1. Umbilical cord. 3. Umbilical vein dividing into three branches; two (4 4) to be distributed to liver; and one (5), ductus venosus, which enters inferior vena cava (6). 7. Portal vein uniting with right hepatic branch. 8. Right auricle; course of blood denoted by arrow, proceeding from 8 to 9, left auricle. 10. Left ventricle; blood following arrow to arch of aorta (11). Arrows 12 and 13, represent return of blood from head and upper extremities through jugular and subclavian veins, to superior vena cava (14), to right auricle (8), and in course of arrow through right ventricle (15), to pulmonary artery (16). 17. Ductus arteriosus, the offsets at each side are right and left pulmonary artery cut off. Descending aorta (18, 18), umbilical arteries (19), external iliacs (20). Arrows at termination of these vessels mark return of venous blood by veins to inferior cava. (Wilson.)

The digestive apparatus exhibits few peculiarities. The bowels, at the full period, always contain a quantity of greenish, or deep black, viscid fæces, to which the term *meconium* has been applied, owing to their resemblance to the inspissated juice of the poppy (μηκων, "a

poppy"). It appears to be a compound of the secretions from the intestinal canal and bile, and frequently contains down or fine hairs mixed with it. It has been analyzed by Dr. John Davy,[1] and found to consist of:—

Mucus and epithelium scales,	23·6
Cholesterin (in plates) and margarin,	·7
Colouring and sapid matter of bile, and olein,	3·0
Water,	72·7
	100·0

Its ashes contained peroxide of iron and magnesia, with a trace of phosphate of lime and chloride of sodium. An analysis by Simon[2] also exhibits that it contains the main constituents of bile:—

Cholesterin,	16·00
Extractive matter and bilifellinic acid,	14·00
Casein,	34·00
Bilifellinic acid and bilin,	6·00
Biliverdin with bilifellinic acid,	4·00
Cells, mucus, albumen,	26·00
	100·00

The liver is very large; so much so as to occupy both hypochondriac regions; and the right and left lobes are more nearly of a size than in the adult. Prior to birth it would seem to be the only decarbonizing organ, the lungs being inactive; but as soon as respiration is established, less blood is sent to the liver; and this diminution takes place with great rapidity, and is usually evidenced a short time after birth by the comparative paleness of its substance. Hence it has been supposed, that the weight of the liver might aid in the determination of the question, whether a child had breathed or not. It has been shown, however, that although the liver, as a general rule, weighs less after respiration has been established, it is by no means the case when the inspiration has been feeble for hours or days after birth; and, on the other hand, it is not uncommon to meet, in infants that have not breathed, with livers as light as in the average of those that have. In the small intestine and the hepatic ducts an albuminous fluid has been found by Drs. Prout and Robert Lee,[3] which seemed to them to be separated from the blood, carried from the placenta to the liver, and to be indirectly inservient to the nutrition of the fœtus. Dr. George Robinson[4] also invariably found in the stomach of the fœtus, during the latter period of its uterine existence, a peculiar substance, differing from the liquor amnii, and generally of a nutritious character, which he regards as the secretion of the salivary glands. The mixture of this substance with the liquor amnii is, he considers, the material submitted to the process of chymification in the fœtal intestines.

The urinary bladder is of an elongated shape, and extends almost to the umbilicus. The muscular coat is somewhat thicker and more

[1] Medico-Chirurgical Transactions, xxvii. 189, Lond., 1844.
[2] Animal Chemistry, Sydenham Society edition, ii. 367, Lond., 1846.
[3] Lectures on the Theory and Practice of Midwifery, Amer. edit, p. 145, Philad., 1844.
[4] London and Edinburgh Monthly Journal of Medical Science, Jan. 1847, p. 507.

irritable than in the adult, and it continues to possess more proportionate power during youth. The common trick of the schoolboy—of sending the jet of urine over his head—is generally impracticable in more advanced life. From the fundus of the bladder, a ligament of a conical shape, called *urachus*, ascends between the umbilical arteries to the umbilicus; becoming confounded there with the abdominal aponeuroses, according to Bichat; and forming a kind of suspensory ligament to the bladder. It is sometimes found hollow in the human fœtus, but Bichat considers such a formation to be preternatural. In the fœtal quadruped, it is a large canal, which transmits urine to the *allantois*, of which, as well as of other fœtal peculiarities, we have previously treated.

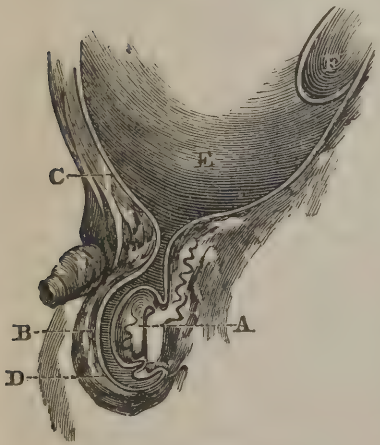
Lastly, the genital organs of the fœtus require notice. The successive developement of this part of the system has given rise to some singular views regarding the cause of sex. During the first few weeks, the organs are not perceptible; but, about the termination of the fifth, a small, cleft eminence appears, which is the rudiment of the scrotum or of the vulva, according to the sex. In the sixth week, an aperture is perceptible, common to the anus and genital organs, in front of which is a projecting tubercle. In the seventh and eighth weeks, this tubercle seems to be tipped by a glans, and grooved beneath by a channel which extends to the anus. In the eleventh and twelfth, the perineum is formed and separates the anus from the genital organs. In the fourteenth the sex is distinct; but there still remains, for some time, a groove beneath the clitoris or penis, which becomes closed in the former, and made into a canal in the latter. This striking similarity between the male and female organs has led Tiedemann[1] to conclude, that the female sex is the male arrested at an inferior point of organization. In his view, every embryo is originally female; the cleft, described above, being the vulva,—the tubercle, the clitoris: to constitute the male sex, the cleft is united so as to form a raphe; the labia majora are joined to form the scrotum; the nymphæ to form the urethra, and the clitoris is transmuted into a penis. In support of this opinion, he asserts, that the lowest species of animals are almost all females; and that all the young acephali and aborted fœtuses, which have been examined, are of that sex. Others, again, assert, that the sexes are originally neuter, and that the future sex is determined by accidental circumstances during the first week of fœtal life; whilst M. Velpeau is disposed to believe, that they are all male—the infrapubic prolongation existing in every embryo, although there may be neither labia majora nor scrotum. Admitting, however, that the embryo belongs to either the one or the other sex, or is neutral, we must still remain at a loss regarding the influences that occasion the subsequent mutations; and it seems impossible not to admit, that although an apparent sexual identity may exist among different embryos, there must be an instinct or force of impulsion seated somewhere, which gives occasion to the sex being ultimately male or female, in the same manner as it causes the young being to resemble one or other parent in

[1] Anatomie der Kopflosen Missgeburten, s. 51, Landshut, 1813.

its external or internal configuration; and if our means of observation were adequate to the purpose, a distribution of arteries or nerves might perhaps be detected, which could satisfactorily account *ab initio* for the resulting sex. In the absence of such positive data, M. Geoffroy St. Hilaire has hypothetically suggested, that the difference of sex may be owing to the distribution of the two branches of the spermatic artery. If they continue in approximation, proceeding together,—the one to the testicle, the other to the epididymis,—the individual is male; if they separate,—the one going to the ovary, the other to the cornu of the uterus,—the individual is female. The degree of predominance of the cerebro-spinal system, he thinks, determines the approximation or separation of the two arterial branches. This predominance being greater in the male, the spermatic arteries are more feeble, and consequently in greater proximity; and conversely in the female;[1] but this suggestion does not remove the obscurity.

Leaving these phantasies of the generalizing anatomists on a subject regarding which we must, probably, ever remain in the dark, let us inquire into the phenomena of the *descent of the testes* in the fœtus. In the early months of fœtal life, the testicle is an abdominal viscus, seated below the kidney. About the middle of the third month, it is about two lines long, and situate behind the peritoneum, which is reflected over its ventral surface. At this time, a sheath of peritoneum may be observed, passing from the abdominal ring to the lower part of the testicle, and containing a ligament, called by Mr. Hunter, who first described it, *gubernaculum testis*, which has been considered to be formed of elastic areolar tissue, proceeding from the upper part of the scrotum, and from the part of the general aponeurosis of the thigh near the ring.

Fig. 448.



Descent of the Testicle.

A. Testicle in scrotum. B. Prolongation of peritoneum. C. Peritoneum lining abdomen. D. Peritoneum forming tunica vaginalis. E. Cavity of peritoneum. F. Kidney.

According to Mr. Curling,[2] it is surrounded by a thin layer of striped muscular fibres, the cremaster, which pass upwards to be attached to the testis; inferiorly the fibres having the same attachments as the cremaster, and being in reality the cremaster inverted. The descent of the testis is effected by the traction of these fibres. During the descent, "the muscle of the testis is gradually everted, until, when the transition is completed, it forms a muscular envelope external to the

[1] Adelon, Physiologie de l'Homme, 2de édit. iv. 375.

[2] Lond. Lancet, April 10, 1841, p. 70; Practical Treatise on the Diseases of the Testis, p. 32, Lond. 1843; and Art. Testicle, Cyclopædia of Anatomy and Physiology, Pt. xxxviii., p. 982. February, 1850.

process of peritoneum, which surrounds the gland and the front of the cord." Prof. E. H. Weber[1] has a similar view. He affirms, as the result of experiments on man, rabbits, and beavers, that the guberna-

Fig. 449.

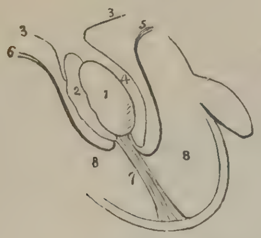
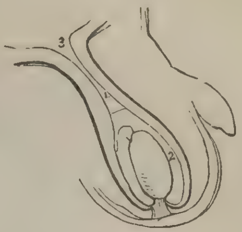


Fig. 450.



Diagrams illustrating the descent of the Testis.

Fig. 449. 1. The testis. 2. The epididymis. 3, 3. The peritoneum. 4. The pouch formed around the testis by the peritoneum. 5. The pubic portion of the cremaster attached to the lower part of the testis. 6. The portion of the cremaster attached to Poupart's ligament. The mode of eversion of the cremaster is shown by these lines. 7. The gubernaculum, attached to the bottom of the scrotum, and becoming shortened by the contraction of the muscular fibres which surround it. 8, 8. The cavity of the scrotum. 9. The peritoneal cavity.

Fig. 450. In this Figure the Testis has completed its descent. The Gubernaculum is shortened to its utmost, and the Cremaster is completely everted. The pouch of Peritoneum above the Testis is compressed so as to form a Tubular Canal.

1. A dotted line marks the point at which the tunica vaginalis will terminate superiorly; and figure 2 its cavity. 3. The peritoneal cavity.

culum originates in the form of a sac in the situation of the inguinal canal. The lower end of this sac extends to the bottom of the scrotum, the upper end extends through the internal abdominal ring as high as the testis, carrying up along with it, to the fold by which that organ is suspended, fibres from the internal oblique muscle. By the aid of the contraction of these fibres, a kind of inversion (Einstülpung) or intussusception of the hollow gubernaculum is induced.

The head of the fœtus in utero being the lowest part, the testis has necessarily to ascend into the scrotum, and consequently some force must be exerted upon it. This is supposed to be effected by the contraction of the gubernaculum testis. About the seventh month, the testes are in progress towards the scrotum, and have attained the inner ring. In this descent, the organ abandons successively one portion of the peritoneum to pass behind another immediately below, until the lowest part of the pouch, formed by the peritoneum, around the testicle, as in Fig. 448, becomes the tunica vaginalis testis; whilst the portion of peritoneum that descended before the testicle becomes, when the testicle has fully descended, the second coat or tunica vaginalis.

As soon as the testicle has reached the lower part of the scrotum, the neck of the pouch approaches a closure, and this is commonly effected at birth. Sometimes, however, it remains open for a time; the intestines pass down, and congenital hernia is thus induced.

The testes have not always descended into the scrotum at birth, even

[1] Müller's Archiv. für Anatomie u. s. w. H. v., s. 403, Jahrgang, 1847.

at the full period; of 97 new-born infants, Wrisberg found both of them in the scrotum in 67: one or both in the canal in 17; one testis in the abdomen in 8; and both in the abdomen in 3.[1] Sometimes, as has been remarked elsewhere, one or both testes remain through life in the abdomen, a condition which is natural in the ram.

2. PHYSIOLOGY OF THE FŒTUS.

In investigating this interesting point of human physiology, we shall inquire into the functions, in the order adopted respecting the functions of the adult. On many of the topics that will have to engage attention, it will be found that the deepest obscurity rests, whilst the hypotheses indulged regarding them have been of the most fanciful and mystic character.

a. *Animal Functions.*

The *external senses* in general are manifestly not in exercise during fœtal life: of this there can be no doubt, as regards the *sense of sight;* and the same thing probably applies to *taste*, *smell*, and *hearing*. With regard to *tact*, however, we have the best reason for believing, that it exists, particularly towards the latter periods of utero-gestation. Either in a senso-motory or reflex manner, the cold hand, applied over the abdomen of the mother, instantly elicits the motions of the child. The brain and nervous system of the fœtus must, therefore, have undergone the developement necessary for the reception of tactile impressions made through the medium of the mother; for conveying such impression to the percipient organ, and accomplishing perception.

The existence of *internal sensations* or *wants* would be supererogatory in the fœtal state, where the functions, to which they minister after birth, are themselves wanting. It is probable, that there is no digestion except of the mucous secretions of the tube; little or no excretion of fæces or urine; and certainly there is no pulmonary respiration. It is not unlikely, however, that internal impressions, originating in the very tissue of the organs, may be communicated to, and appreciated by, the encephalon. We have strong reason for believing, that pain may be experienced by the fœtus; for if it be destroyed by any sudden influence in the later periods of pregnancy, death is generally preceded by irregular movements manifest to the mother, and frequently leading her to anticipate the result. M. Adelon asks, whether it may not be affected, under such circumstances, with convulsions, similar to those that animals experience when they die suddenly, especially from hemorrhage? It is impossible to reply positively to the question; but that the child suffers appears evident.

The most elevated of the functions of relation—the *mental* and *moral faculties*—would seem to be needless in the fœtus; and consequently can be little, if at all, exercised. MM. Bichat and Adelon,[2] considering that its existence is purely vegetative, are of opinion that they are not exerted. M. Cabanis,[3] however, suggests, that imperfect essays

[1] Comment. Soc. Reg. Scient. Gotting., 1778.
[2] Physiologie de l'Homme, 2de édit. iv. 420, Paris, 1829.
[3] Rapport du Physique et du Moral de l'Homme, Paris, 1802.

may, at this early period, be made by virtue of the same instinct, that impels animals to exercise their organs prior to the period at which they are able to derive service from them; as in the case of the bird, which shakes its wings before they are covered with feathers. It is difficult to deny to the fœtus *all* intellectual and moral manifestations. They must, doubtless, be obscurely rudimental; still, we may conceive that some may exist, if we admit that the brain is in a state for the perception of impressions; that tact is practicable, and instinct in full activity. We find, moreover,—that the power of *motion*, voluntary as well as involuntary, exists after the fifth month, and probably much earlier, could it be appreciated. During the latter months of utero-gestation, the motion appears to be almost incessant, and can be distinctly felt by placing the hand upon the abdomen. At times, indeed, it is manifest to the sight. The cause of these movements is by no means clear. It is probable, that they are instituted for the purpose of changing the position, which may have become irksome; for we have already remarked, that the fœtus readily appreciates any sudden succussion given to it through the mother, and hence that it possesses tact, and, as we can readily understand, may experience fatigue from the maintenance of an inconvenient posture, and send nervous influence to the appropriate muscles to change it. Dr. Simpson[1] maintains, that the motions are altogether excito-motory; and that the position of the fœtus in utero, or—as he expresses it—"the adaptive position of the contained to the containing body is the aggregate result of reflex movements on the part of the fœtus by which it keeps its cutaneous surface as far as possible from causes of irritation." All this proves, that the encephalic and spinal functions are exerted; but only for a few definite objects.

The function of *expression* is almost, if not entirely, null in the fœtus. There are cases on record, where children are said to have cried in utero, so as to have been heard distinctly, not only by the mother, but by those around her. Indeed, the objection, that an infant may respire before it is born, and yet not come into the world alive,—in which case there will be buoyancy and dilatation of the lungs,—has been brought forward against the docimasia pulmonum or *lung-proof* of infanticide. It is impossible for us to consider the cases of the kind that have been recorded as mere fabrications, or the phenomenon to be impossible,—except, indeed, whilst the membranes are in a state of integrity. When they have given way, and the child's mouth presents towards the os uteri, breathing and *vagitus* may be practicable; yet very positive and unexceptionable testimony is required to establish such an occurrence.[2]

b. *Functions of Nutrition.*

These functions are not as numerous in the fœtus as in the adult. Their object is, however, the same,—the formation of the various parts

[1] Edinb. Monthly Journal of Science, July, 1849.

[2] Taylor, Medical Jurisprudence, 2d Amer. edit., by Dr. R. E. Griffith, p. 381, Philad., 1850.

of the organized machine, and the constant decomposition and renovation.

One of the least tenable hypotheses, that have been entertained regarding the embryo at its first formation is,—that, for the first month —and why the period is thus limited is not apparent—the vitality of the fœtus is not independent, but is a part,—an offset, as it were,—of that of the mother; that it has no separate powers of existence; no faculty of self-evolution; and that its organs are nourished by the plastic materials, which it incessantly derives from the maternal blood. It appears manifest, that from the very moment of the union of materials furnished by both sexes at a fecundating copulation, the elements of the new being must exist; and that it must possess, within itself, the faculty of self-evolution; otherwise, how can we understand the phenomena, that take place in the ovary after fecundation. It is admitted, that this organ furnishes the unfecundated ovum; and that the sperm must come in contact with it; after which, fecundation is accomplished, and immediately the ovum undergoes a farther developement; escapes, in due time, from the viscus in which it was formed; is laid hold of by the Fallopian tube; passes through that canal, and is deposited in the interior of the uterus, with which it ultimately contracts adhesions. But all this requires time. The ovum does not probably reach the uterus, in the human female, before ten or twelve days; and some time must still elapse before such adhesions are effected; and, consequently, before anything like maternal blood, whence the plastic materials are derived, according to the view in question, could be sent to it. During this time, the embryo must derive its nourishment from the nutritious matters with which it is surrounded in the ovum in the same manner as the young of the oviparous animal, during incubation, obtains the nutriment necessary for its full developement from the matters surrounding it.

The albuminous and oily contents of the ovum, surrounding the embryo of the oviparous animal, would seem to resemble greatly the milk of the mammalia both physically and chemically, and M. Joly[1] has recently suggested the following points of similarity. "The milk is composed essentially of fatty matter—butter, suspended under the form of globules in an albuminoid fluid—casein; and it contains water, sugar of milk, and salts; amongst others, phosphate of lime, so eminently useful for the consolidation of the bones of the young being that feeds upon it. In the egg there are vitelline globules, which contain a fat oil, susceptible of congelation on cooling,—evidently the *analogue* of butter and the globules that contain it. In the egg are, likewise, albumen, and *vitelline*, which is a very slight modification of it. Now, it is admitted by chemists, that albumen, vitelline, animal protein and animal fibrin differ so little from casein, that all these substances may be, and in fact are, confounded under the common denomination of albuminoid or proteiform matters. Moreover, Winckler, Barreswil, and, quite recently, M. Braconnot, from whom I have learned this interesting fact, have discovered sugar of milk in eggs; and every one is

[1] Comptes Rendus, No. 20, 12 Novembre, 1849, p. 524.

aware that, as in the milk itself, water and salts are found and particularly phosphate of lime. It may be added, that on treating the hen's egg like the milk of the mammalia, and by the same chemical agents (alcohol, sulphuric ether, and acetic acid), I have obtained almost the same reactions."

In due time, after the ovum has reached the interior of the uterus, it is compelled to absorb appropriate nutriment from the mother;—the minute quantity existing in the ovum, at this early period, being insufficient for the developement which it is destined to attain. In this last respect, the human ovum differs from the egg of an oviparous bird, which is hatched out of the body, and contains sufficient nutriment for full fœtal evolution. In treating of this subject, Dr. Granville[1] has the following remarks.—"What stronger proof need be required of the existence of an adherent life principle in the ovulum, which is, at one time at least, indeed, I suspect throughout the period of gestation, independent of any connexion with the parent mother? Yet none of the earlier writers who adopted the ovarian theory of generation have ever asked themselves this question:—what supports the vitality of a fecundated ovulum after it has left the ovarium, and previously to its becoming connected with the womb? In fact, the subject had never been mooted, before the more modern physiologists took it up and satisfactorily explained it:"—and he adds in a note:—"the whole of the English physiologists, writers on midwifery, and lecturers, whether ancient or modern, are entirely silent on this important stage of embryonic life." It is a topic, however, discussed at length in the first edition of this work, which was published before that of Dr. Granville, and is much expanded in the subsequent editions.[2]

Since the time of Hippocrates, Aristotle, and Galen, different anatomists and physiologists have asserted, that the umbilical vein is the only channel through which nutriment reaches the fœtus; in other words, that the whole of the nourishment which it receives is from the placenta; but the facts, to which allusion has already been made, are sufficient to overturn this hypothesis. It is impossible, that the placenta can have any agency until it is *in esse*. Such an explanation of the process of fœtal nutrition could only hold good after the first periods, and then, as we shall see, it is sufficiently doubtful. Accordingly, some of the most distinguished modern physiologists, who have devoted their attention to embryology, have completely abandoned the idea of placental agency during the first months; and they, who have invoked it at all, have usually done so as regards the after periods only. On all this subject, however, we have the greatest diversity of views. Lobstein,[3] for example, affirms, that the venous radicles of the rudimental placenta obtain nutritive fluids from the mother during the first days only, until the period when the arteries are formed; but that, after this, all circulation between the uterus and placenta ceases, and the fluid of the umbilical vesicle, the liquor amnii, and the jelly of the cord, are the materials of nutrition. Meckel[4] thinks the placenta is

[1] Graphic Illustrations of Abortion, p. vii., Lond. 1834.
[2] Human Physiology, 1st edit. ii. 365, Philad. 1832.
[3] Essai sur la Nutrition du Fœtus. Strasbourg, 1802.
[4] Handbuch, u. s. w., Jourdan and Breschet's French translation, iii. 1784.

never the source of nutritive materials. He regards it as an organ for the vivification of the blood of the fœtus, analogous to the organ of respiration in the adult; and nutrition is, in his opinion, accomplished by the matter of the umbilical vesicle in the beginning, by the liquor amnii until midterm, and by the jelly of the cord until the end. According to M. Béclard,[1] nutrition is effected, during the first weeks, by the fluid of the umbilical vesicle; afterwards, by the liquor amnii, and the jelly of the cord; and as soon as the ovum becomes villous, and developes the placenta, by that organ. Dr. Montgomery[2] has described several "decidual cotyledons," as he terms them, which are best seen about the second or third month, and are not to be found at the advanced period of gestation. These are small cup-like elevations on the external surface of the decidua uteri, having the appearance of little bags, the bottoms of which are attached to, or embedded in, its substance; they then expand a little, and again grow smaller towards their outer or uterine end, which, in by far the greater number of them, is an open mouth when separated from the uterus: how it may be when adherent he does not profess to say, nor does he offer any decided opinion as to their precise nature or uses; but, from having on more than one occasion observed within their cavity a milky or chylous fluid, he is disposed to consider them reservoirs for nutrient fluids separated from the maternal blood, to be thence absorbed for the support and developement of the ovum. "This view," says Dr. Montgomery, "seems strengthened when we consider, that at the early periods of gestation, the ovum derives all its support by imbibition, through the connexion existing between the decidua and the villous processes covering the outer surface of the chorion. M. Adelon[3] is of opinion, that two sources of nutrition ought alone to be admitted,—the umbilical vesicle, which is the sole agent for nearly two months, and the placenta for the remainder of the period. M. Velpeau[4] equally thinks, that the nutriment of the ovum is derived from different sources at different periods of intra-uterine existence. The embryo, he says, is at first but a vegetable, imbibing the surrounding humours. The villi of its circumference, which are true cellular *spongioles*, obtain nutritive principles in the Fallopian tube and the uterus, to keep up the developement of the vesicles of the embryo; after which the new being is nourished like the chick in *ovo*, or rather like the plantule, which is, at first, altogether developed at the expense of principles enclosed in its cotyledons. It gradually exhausts the vitelline substance contained in the umbilical vesicle. The emulsive substance of the reticulated sac of the allantoid pouch is also gradually absorbed. The end of the second month arrives; the vessels of the cord are formed, and the placenta is developed; by its contact with the uterus, this organ obtains reparatory materials; elaborates them; and forms from them a fluid more or less analogous to blood, which fluid is absorbed by the radicles of the umbilical vein.

1 Embryologie ou Essai Anatomique sur le Fétus Humain, Paris, 1821.
2 Signs and Symptoms of Pregnancy, p. 133, Lond., 1837.
3 Physiologie de l'Homme, 2de édit. iv. 397, Paris, 1829.
4 Embryologie ou Ovologie, &c., Paris, 1833; and Traité Elémentaire de l'Art des Accouchemens, Professor Meigs's translation, 2d edit. p. 213, Philad., 1838.

The views of Professor Goodsir on this subject have been referred to already (p. 546 and p. 549).

We find, consequently, some of the most distinguished physiologists denying—as it would seem that every one ought to do—that the nutrition of the fœtus takes place solely from blood sent by the mother to the fœtus. If we search into the evidence afforded by transcendental anatomy, we find that amidst the various singular monstrosities met with, there would appear to be but one thing absolutely necessary for fœtal developement,—an absorbing surface, surrounded by a nutritive substance, capable of being absorbed. Head, heart,—every thing, in short, except organic nervous system, vessels, and areolar tissue,—may be wanting, and yet the fœtus may grow so as to attain its ordinary dimensions. We have the most incontestable evidence, that neither the placenta nor umbilical cord is indispensably necessary for fœtal developement. M. Adelon disposes of this in the most summary manner, by affirming, that "there is no authentic instance of a fœtus, devoid of umbilical cord and placenta, attaining full uterine growth." The case is not, however, got rid of so easily. Marsupial and monotrematous animals are non-placental, or breed their young without either positive placenta or cord. The embryos are enclosed in one or more membranes, which are not attached to the coats of the uterus, and are supplied with nourishment from a gelatinous matter by which they are surrounded. Thomas Bartholin, during his travels in Italy, saw an individual, forty years old, who was born without anus, penis, or umbilicus; and M. Velpeau cites similar cases from Ruysch, Samson, Chatton, Rommeil, Denys, Fatio, V. Geuns, Suc, Penchienati, Franzio, Desgranges, Kluyskens, Pinel, Mason, Osiander, Dietrich, Von Froriep, and Voisin; but as these cases militate against his views of embryotrophy, he attempts to diminish their force by affirming, that the observations, which he had made, satisfy him, that all the fœtuses thus born had died in utero, in consequence of the destruction of the cord, or the closure of the umbilicus; or else, that the umbilicus existed, but was hidden or lost in the extroversion of the bladder almost always remarked in those that lived. Passing by the singular deduction of M. Velpeau, that his observations have satisfied him of the incorrectness of those made by observers, many of whom have long since left the stage,—long before he existed,—as well as the facts relating to the marsupial animal, and that the fœtus, in extra-uterine pregnancies, has frequently no placenta,—with the case cited by Dr. Good, from Hoffmann, of a fœtus born in good health and vigour, the funis sphacelated and divided into two parts; and one by Stalpart Van der Wiel,[1] of a living child, exhibited without any umbilicus as a public curiosity,—a case observed by Dr. Good[2] himself, appears to be unanswerable. The case in question occurred in 1791. The labour was natural; the child, scarcely less than the ordinary size, was born alive; cried feebly once or twice after birth, and died in about ten minutes. The organization, both internal and external, was imperfect in many

[1] Observat. Rar. Med. Chirurg. cent. ii., p. 1, Obs. 32.

[2] Case of Preternatural Fœtation with Observations, read before the Medical Society of London, Oct. 20, 1794; and Study of Medicine, in Physiological Proem to Class v. Genetica.

parts. There was no sexual character; neither penis nor pudendum; nor any internal organ of generation. There was no anus, no rectum, no funis, no umbilicus. The minutest investigation could not discover the least trace of any. With the use of a little force, a small, shrivelled placenta,—or rather the rudiment of a placenta,—followed soon after the birth of the child, without funis or umbilical vessels of any kind, or any appendage by which it appeared to have been attached to the child. In a quarter of an hour afterwards, a second living child was protruded into the vagina and delivered with ease, being a perfect boy, attached to its placenta by a proper funis. The body of the first child was dissected in the presence of Dr. Drake of Hadleigh, and of Mr. Anderson of Sunbury, to both of whom Dr. Good appeals for the correctness of his statement. In the stomach, a liquor was found resembling liquor amnii.

How could nutrition have been effected, then, in this case? Certainly not by blood sent from the mother to the child, for no apparatus for its conveyance was discoverable; and are we not driven to the necessity of supposing, that nutriment must have been obtained from the fluid within the ovum? This case,—with the arguments already adduced,—seems to constrain us to admit, that the liquor amnii may have more agency in the nutrition of the new being than is generally granted. Professor Monro,[1] amongst other reasons,—all of which are of a negative character,—for his disbelief in this function of the liquor amnii, asserts, that if the office of the placenta be not that of affording food to the embryo, it becomes those, who maintain the contrary doctrine, to determine what other office can be allotted to it; and that till this is done it is more consistent with reason to doubt the few and unsatisfactory cases, at the time brought forward, than to perplex ourselves with facts directly contradictory of each other. The case given by Dr. Good, since Professor Monro's remarks were published, is so unanswerable, and so unquestionable, that it affords a positive fact of full, or nearly full, fœtal developement, independently of placenta and umbilical cord; and the fact must remain, although our ignorance of the functions of the placenta may be "dark as Erebus."

The following case, with which the author was obligingly favoured by his friend, Dr. Wright, of Baltimore, has an instructive bearing upon the subject. The condition of the placenta was such as to lead that intelligent observer to conclude, that any circulation between the mother and the fœtus, through the placenta, was impracticable.

"*Baltimore*, September 26th, 1835.

"Dear Sir,—In compliance with your request, I offer you the following plain and short statement of a case, which occurred in my practice, at the date indicated.

"On the 6th of December, 1833, I was requested to visit Mrs. T——, of this city, —a young woman of large frame, good constitution, and generally excellent health. She had been married about fifteen months, and I was now called to attend her first labour. She had felt occasional labour pains through the day, and was delivered of a fine, vigorous female infant, in about four hours from the time of my call. The labour was, in all respects, natural, and as easy as is common—or consistent—with a first parturition. After the birth of the child, an hour, perhaps, was passed in waiting for secondary pains to effect the expulsion or favour the removal of the

[1] Edinburgh Medical Essays, ii. 102.

placenta, but no movement of this kind having then occurred, a gentle examination was made to ascertain whether that body might be easily and properly taken away. The vagina contained nothing more than the funis—the outlet of the uterus was open, soft and extensible. The cord was gently followed into the uterine cavity, and the cake found near its fundus, retaining a close connexion with the uterus. The placental mass was large and firm, presenting to the touch a peculiar feeling—as of a dense sponge, full of coarse, granular or gravelly particles. Deeming it now proper to relieve the patient fully, a cautious effort was made to detach the placenta from the uterus, in order to its manual extraction. In pursuing this design, it was found, that the adhering surface of the former consisted of a uniform calcareous lamina or plate, rough to the finger, and exciting such a sensation or feeling as would be caused by a sheet of coarse sand-paper. When the mass was detached, and brought away, the laminar surface, just referred to, was found to be a calcareous plate, uniformly covering the whole of the attached portion of the cake,—the entire surface of the utero-placental connexion. The calcareous matter, thus distributed, was thin, and readily friable, but, as before remarked, it appeared to constitute a uniform and superficial covering. The correspondent uterine surface—the part from which the placenta had been separated—felt rough, but comparatively soft, imparting nothing distinctly of the calcareous or gritty feel. Out of the body, the placenta felt heavy, and eminently rough throughout. When compressed or rubbed together, the large amount of nodular or granular matter, dispersed through its substance, was not only manifest to the touch, but a very audible crepitation or grating sound could be thus elicited from any and every part of the mass.

"In this uncommon instance of placental degeneracy, both the mother and child were perfectly healthy and well. The latter, indeed, was remarkable for its fine size, perfect nutrition and vigour. From the condition of the cake, and the character of its adhesion to the uterus, I apprehended a more than ordinary liability to secondary affection, in the form of puerperal fever,—and whether influenced or not by the circumstances detailed, secondary fever did ensue on the third day from delivery, attended by the usual signs of puerperal hysteritis, which affection, however, was happily subdued by general and topical bleeding, calomel, &c.

"With sincere regard, yours,

"T. H. Wright.

"Professor Dunglison.

"P. S.—The child, referred to, is living, and, from its birth to the present, has considerably exceeded the common bulk of children at the same age. The mother is now far advanced in her second pregnancy."

Since this letter was written, the same lady has been delivered of another healthy child. The maternal surface of the placenta was of the like calcareous character; but the deposition was not to the same extent as in the first pregnancy. A similar case has been described by Mr. Gilbert, of Beaminster, England.[1]

That the liquor amnii is possessed of nutritive properties is shown not only by its containing albumen, and, it is said, osmazome; and by the fact, that new-born calves have been nourished for a fortnight on fresh liquor amnii;[2] but amongst those physiologists, who admit it to be a fluid destined for fœtal nutrition, a difference prevails regarding the mode in which it is received into the system. Osiander,[3] Brugmans,[4] Van den Bosch, Fohmann, Carus,[5] and others, think it is absorbed through the skin. In the fœtal state, the cuticle is extremely thin, and, until within a month or two of the full period, can be scarcely said to

[1] Lancet, for Dec. 16, 1837, p. 418.
[2] Cazeaux, Traité Théorique et Pratique de l'Art des Accouchements, p. 176, Paris, 1840.
[3] Handbuch der Entbindungskunde, B. i., s. 237.
[4] De Naturâ et Utilitate Liquoris Amnii, Ultraject., 1792.
[5] Lehrbuch der Gynäkologie, Th. ii., s. 27, Leipz., 1828.

exist. There is not, consequently, that impediment to cutaneous absorption which, we have seen, exists in the adult. The strong argument, however, which they offer in favour of such absorption is the fact, that the fœtus has been developed, although devoid of both mouth and umbilical cord; and Professor Monro, in opposing this function ascribed to the liquor amnii, refers to cases of monstrous formation, in which no mouth existed, nor any kind of passage leading to the stomach. Others, as Haller[1] and Darwin,[2] are of opinion, that the fluid enters the mouth and is sent on into the stomach and intestines; and in support of this view they affirm, that the liquor amnii has been met with in these organs. Heister, on opening a gravid cow that had perished from cold, found the liquor amnii frozen, and a continuous mass of ice extending to the stomach of the fœtus.[3] Observations, by Dr. George Robinson,[4] on fœtal animals more especially, have led him to affirm, that in the earlier stages of the developement of the fœtus, the contents of the stomach consist chiefly of liquor amnii, to which a peculiar matter is added, which—as before remarked—he refers to the salivary glands. He states, moreover, that the liquor amnii continues to be swallowed until birth, and the mixture of this with the peculiar salivary secretions, is the material subjected to chymification; yet he ascribes the main agency in fœtal nutrition, in the later months, to the "placental vessels."

Physiologists who believe, that the liquor amnii is received into the stomach, differ as to what happens to it in that organ. Some suppose, that it is simply absorbed without undergoing digestion; others, that it must be first subjected to that process. According to the former opinion, it is simply necessary, that the fluid should come in contact with the mucous membrane of the alimentary passages; and they affirm, that if digestion occurs at all, it can only be during the latter months. Others, however, conceive, that the waters are swallowed or sucked in, and undergo true digestion. In evidence of this they adduce the fact of meconium existing at an early period in the intestinal canal, which they look upon as evidence that the digestive function is in action; and, in further proof, they affirm, that on opening the abdomen of a new-born infant the chyliferous vessels were found filled with chyle, which could not, they say, have been formed from any other substance than the liquor amnii; and lastly, that fine silky down has been found in the meconium, similar to that which exists on the skin of the fœtus, and which is conceived to have entered the mouth along with the liquor amnii. These reasons have their weight, but they cannot explain the development in the cases above alluded to, in which there was no mouth; and of course cannot apply to the acephalous fœtus. Moreover, it has been properly remarked, that the presence of meconium in the intestinal canal—admitting that it is the product of digestion, which is denied by many—merely proves, that digestion has taken place, and the same may be said of the chyle in the chyliferous vessels: neither one nor the other is a positive evidence of digestion of the

[1] Elementa Physiologiæ, viii. 205. [2] Zoonomia, vol. ii., p. 203, London, 1801.
[3] Adelon, Physiologie de l'Homme iv. 389, Paris, 1829.
[4] London and Edinburgh Monthly Journal of Medical Science, Jan. 1847, p. 512.

liquor amnii. Both might have proceeded from the stomachal secretions. It has also been affirmed, that meconium exists in the intestines of the acephalous fœtus; and in those in which the mouth is imperforate. Lastly, with regard to the down discovered in the meconium, it has been suggested as possible, that it may be formed by the mucous membrane of the intestine, which so strongly resembles the skin in structure and functions.

Others have supposed, that the liquor amnii is received through the respiratory passages, from the circumstance, that in certain cases the fluid has been found in the trachea and bronchia:—some presuming, that it readily and spontaneously enters the nostrils and passes to the trachea and bronchia; others, that it is forced in by the pressure of the uterus; and others, again, that it is introduced by the respiratory movements of the fœtus. Views have differed in this case, also, regarding the action exerted upon it after introduction; some presuming that it is absorbed immediately; others, that it is inservient to a kind of respiration; and that, during fœtal existence, we are aquatic animals,—consuming the oxygen or atmospheric air, which Scheele,[1] Lassaigne,[2] and others have stated to exist in it. It is scarcely necessary to oppose these gratuitous speculations seriously. The whole arrangement of the vascular system of the fœtus, so different from that which is subsequently established, and the great diversity in the lungs, prior and subsequent to respiration, would be sufficient to refute the idea,—had it even been shown, that the liquor amnii always contains one or other of these gases, which is by no means the fact. The case of the acephalous fœtus is likewise an obstacle to this view as strong as to that of the digestion of the liquor amnii.

As if to confirm the remark of Cicero—"nihil tam absurdum, quod non dictum sit ab aliquo philosophorum,"—it has been advanced by two individuals of no mean pretensions to science, that the liquor amnii may be absorbed by the genital organs, or by the mammæ. Lobstein[3] supports the former view; Oken[4] the latter. Oken asserts, that the fluid is laid hold of by the mammæ, is elaborated by them, and thence conveyed into the thymus gland, the thoracic duct, and the vascular system of the fœtus. Hence, the necessity of both sexes possessing nipples before birth. Of these various opinions, the one that assigns the introduction of the fluid to the agency of the cutaneous absorbents appears to carry with it the greatest probability. It must be admitted, however, that the whole subject is in obscurity, and requires fresh, repeated, and accurate experiments and observations. But it may be asked, with Dr. Monro, what are the nutritive functions performed by the placenta? We have before alluded to the different views entertained regarding the connexion between the placenta and the uterus. Formerly, it was universally maintained, that vessels pass between the mother and the maternal side of the placenta, and that others pass between the fœtus and the fœtal side, but that the two sides are so distinct, as to justify their being regarded as two placentæ,—the one

[1] De Liquoris Amnii Utilitate, Copenhag., 1795. [2] Archiv. Général. de Méd., ii. 308.
[3] Essai sur la Nutrition du Fœtus, p. 102, Strasbourg, 1802.
[4] Zeugung, p. 162, Bamberg, 1805.

maternal, the other fœtal,—simply united to each other. At one time, again, it was supposed, that a direct communication exists between the maternal and fœtal vessels, but this notion has long been exploded. We have decisive evidence, that the connexion is of the most indirect nature. Wrisberg made several experiments, which showed, that the circulatory apparatus of the fœtus is not drained when the mother dies of hemorrhage. It has been affirmed, too, that if the uterine arteries be injected, the matter of the injection passes into the uterine veins, after having been effused into the lobes of the placenta. If, on the other hand, the injection be thrown into the umbilical arteries it passes into the umbilical vein, and is effused into the placenta, but does not enter the uterine vessels. When, however, an odorous substance, like camphor, is injected into the maternal veins of an animal, the fœtal blood ultimately assumes a camphorated odour: when animals have been fed on madder during gestation, the colouring matter has been found in the fœtus;[1] and, when the human female has taken rhubarb, evidence of it has been found in the liquor amnii, in the serum of the blood of the umbilical vessels, and in the first urine of the infant.[2] M. Magendie[3] injected this substance into the veins of a gravid bitch, and extracted a fœtus from the uterus at the expiration of three or four minutes: the blood did not exhibit the slightest odour of camphor; whilst that of a second fœtus, extracted at the end of a quarter of an hour, exhibited it decidedly. Such was the case, also, with the other fœtuses. The communication may, however, have been owing to the same kind of transudation and imbibition, of which we have spoken under the head of Absorption, and might, consequently, be regarded as entirely adventitious; and the fact of the length of time required for the detection of the odorous substance favours the idea; for if any direct communication existed between the mother and fœtus, the transmission ought certainly to have been effected more speedily. The transmission of substances from the fœtal to the maternal placenta is still more difficult. M. Magendie was never able to affect the mother by poisons injected into the umbilical arteries, and directed towards the placenta; and he remarks, in confirmation of the results of the experiments of Wrisberg, that if the mother dies of hemorrhage, the vessels of the fœtus remain filled with blood. They who consider, that there is no maternal and fœtal portion of the placenta, or, rather, that it is all fœtal, of course believe, where the matter of injection, thrown into the uterine vessels, has passed into the cells of the placenta, that it has been owing to the rupture of parts by the force with which the injection has been propelled.

Another fact, which proves the indirect nature of the connexion that exists between the parent and child, is the total want of correspondence between the circulation of the two. By applying the stethoscope to the abdomen of a pregnant female, the beating of the fœtal heart is observed to be twice as frequent as that of the mother. (See p. 498 of this volume.) Again, examples have occurred in which the fœtus

[1] Mussey, in Amer. Journ. of the Med. Sciences for November, 1829.
[2] Granville, Graphic Illustrations of Abortion, &c., p. xx., Lond., 1834.
[3] Précis Elémentaire, ii. 552.

has been extruded with the placenta and membranes entire.[1] In a case of the kind that occurred to Wrisberg, the circulation continued for nine minutes; in one described by Osiander,[2] for fifteen minutes; in some, by Professor Chapman, from ten to twenty minutes; and in one, by Professor Channing, of Boston, and Dr. Selby, of Tennessee, where a bath of tepid water was used to resuscitate the fœtus, for an hour.[3] Marson[4] and Flajani relate cases in which life continued for the same time: Dr. Nehr,[5] of Rehau, in Bavaria, has recorded one in which the circulation of the child was unequivocal for seven hours after the sudden and decided death of the mother; and others are referred to by D'Outrepont in his comments on this.[6] In cases of a similar kind, where the child could scarcely breathe and was in danger of perishing, the life of the placenta was maintained by keeping it in water of a temperature nearly equal to that of the body, and the child was saved. All these facts prove demonstratively, that the fœtus carries on a circulation independently of that of the mother; and whatever passes between the fœtal and maternal vessels is probably exhaled from the one and absorbed by the other, as the case may be. The fluid sent to the fœtus is supposed by some—indeed by most—physiologists to be the maternal blood, modified or unmodified. Schreger,[7] however, and others maintain, that the communication of any nutritious fluid from the mother to the fœtus, and conversely, takes place by means of lymphatics, and not by bloodvessels; and that the maternal vessels exhale into the spongy tissue of the placenta the serous part of the blood, which is taken up by the lymphatics of the fœtal portion, and conveyed into the thoracic duct. The views of Mr. Goodsir in regard to the absorbing tufts of fœtal vessels have been given already, when describing the placenta.

It has been remarked before, that Lobstein[8] and Meckel[9] suppose, that the gelatinous substance of the cord is one of the materials of fœtal nutrition; which opinion they found on the circumstance of the albuminous nature of the substance, and the great size it gives to the cord at the early periods of fœtal life, as well as on the great developement of the absorbent vessels of the fœtus, which proceed from the umbilicus to the anterior mediastinum;—and that others include, also, the fluids of the umbilical and allantoid vesicles. All these speculations regarding the various sources of nutritive matter are sufficient evidence of the uncertainty that prevails on this interesting topic. It is manifest, however, that we cannot regard those substances to be nutritive to the fœtus which are secreted by itself. It is impossible, that any developement can occur without the reception of materials from without. We have seen, that when the ovum passes from the ovarium to

[1] Granville, op. cit. part x., London, 1834.
[2] Annalen, B. i. s. 27.
[3] Horner's Special and General Anatomy, 5th edit., ii. 277, Philad., 1839.
[4] Lond. Med. Gazette, August, 1833.
[5] Neue Zeitschrift für Geburtskunde, von Busch, D'Outrepont und Ritgen, Band. iv. Heft 1, s. 58, Berlin, 1836.
[6] Ibid. s. 60.
[7] De Functione Placentæ Uterinæ, Erlang., 1795.
[8] Essai sur la Nutrition du Fœtus, Strasbourg, 1812.
[9] Handbuch, u. s. w., Jourdan and Breschet's translation, iii. 785, Paris, 1825.

the uterus, it contains, within it, a molecule, and fluids destined probably for its nutrition, and which afford the necessary pabulum for the increase, that occurs between the period of impregnation and that at which an adhesion is formed between the ovum and the inner surface of the uterus. The mother, having provided the nutritive material in the ovum, she must continue to do so in the uterus; and as soon as the vascular communication is formed between the exterior of the ovum and the interior of the uterus, nutritive elements are doubtless received by the embryo;—for otherwise it would perish from inanition. What, then, it has been asked, can be the nature of these elements? Do they consist of maternal blood, laid hold of by the fœtus at this early period, when no circulatory system is apparent; or are bloodvessels distributed to the membranes of the ovum, to enable them to continue the secretion of a nutritive matter, similar to that which they took with them from the ovarium, and which must necessarily have had a maternal origin? Neither supposition is probable; yet there is great reason for the belief, that the liquor amnii is secreted from the interior of the uterus, and passes through the membranes of the ovum by imbibition. If we admit it to be, indeed, in any manner inservient to nutrition, its production must be extraneous to the body it has to nourish. These observations apply equally to the jelly of the umbilical cord, which probably passes through the membranous envelopes, and may consequently be regarded as a nutritive material derived from the parent. Both, it is true, might be secreted by the fœtus from fluids furnished by the mother, and be placed in depot, as the fat is in after existence.

Philosophical Anatomy, then, instructs us, that the placenta and umbilical cord are not indispensable to fœtal nutrition; and compels us to infer with Meckel[1]—one of the most eminent of modern anatomists and physiologists—and with M. Cazeaux[2] and others—that the human placenta may have no direct agency in embryotrophy. We are, therefore, necessarily driven to the conclusion, before stated,—that, in order for a fœtus to be developed in utero, it is but necessary, that there shall be an absorbing surface, surrounded by a nutritive substance, that will admit of being absorbed. Now, the cutaneous envelope of the fœtus—monstrous or natural—is such a surface, and the liquor amnii such a fluid; and the matter of the umbilical vesicle, with the jelly of the cord, when these parts exist, and possibly some material derived through the placenta, after it exists, may lend their aid; but the participation of these last is—to say the least—doubtful. The function of the placenta probably is to admit of the fœtal blood being *shown* to that circulating in the maternal vessels, so that some change may be effected in the former, which may better adapt it for serving as the pabulum, whence the secretions, from which the fœtal organs have to be elaborated, may be formed. According to Dr. Reid,[3] the blood of the mother, contained in the placental sac already described, and the blood of the fœtus contained in the umbilical vessels, can readily act and react on each other,

[1] Op. citat.
[2] Op. cit.: or translation by Dr. R. P. Thomas, p. 216, Philadelphia, 1850.
[3] Edinb. Med. and Surg. Journ., Jan. 1841, p. 8.

through the spongy and cellular walls of the placental vessels and the thin sac ensheathing them, in the same manner as the blood in the bronchial vessels of aquatic animals is acted upon by the water in which they float. If we admit this, however, it is obvious, that the nutritive fluid, when received into the system, will have to be converted into blood by the action of the fœtus, in a manner bearing some analogy to what occurs in the adult, or in the simplest of living beings, in which the nutritive fluid is absorbed at the surface of the body. Of the mode in which such conversion is effected we are in the darkness that envelopes all the mysterious processes which are esteemed organic and vital; but that the fœtus is capable of effecting it we have irrefragable proof in the oviparous animal, where there can be no communication, after the egg is laid, between the embryo and the parent. Yet we find it forming its own blood from the yolk that surrounds it, and undergoing its full and regular developement from impulses seated in itself alone.

Of those physiologists, who consider that the mother sends her blood to the placenta, to be taken up by the fœtal vessels, all do not conceive that it is in a state adapted for the nutrition of the new being: some are of opinion that the placenta, or the liver, or both, modify it. but in a manner which they do not attempt to explain. In favour of an action being exerted by the placenta, they state that it is clearly the organ which absorbs the fluid, and that every organ of absorption is necessarily one of elaboration;—a principle which we have elsewhere proved to be unfounded; and, moreover, that the blood conveyed to the fœtus by the umbilical vein differs essentially in colour from that conveyed to it by the umbilical arteries, which, we shall see, is not the fact; and, if it were, could be accounted for more satisfactorily. In support of the view, that a second change is effected in the liver, they affirm, that a great part of the fœtal blood ramifies in the substance of that organ before it reaches the heart; a part only going by the ductus venosus; and that the great size of the liver, during fœtal life, when its function of secreting bile can be but sparingly exerted, is in favour of this notion.[1] The opinion, that some change is effected upon the blood in the liver, is certainly much more philosophical and probable than the belief of Haller, that the object of its passage through that organ is to deaden the force with which the mother projects the fluid into the fœtal vessels. We have seen, that it is extremely doubtful, whether she transmits any; and that if she does, the communication is very indirect. M. Geoffroy Saint-Hilaire[2] appears to think, that the blood of the mother, which he conceives to be sent through the placenta to the fœtus, is unfitted for fœtal life, before it has undergone certain modifications. That, according to him, which leaves the placenta, proceeds in part to the liver, and the remainder to the heart. In the liver it forms the material of the biliary secretion, or at least of a fluid, which, when discharged into the intestines, irritates them, and provokes a copious secretion from the mucous or lining

[1] Velpeau, Traité de l'Art des Accouchemens; or Meigs's translation, 2d edit., p. 224, Philad., 1838.

[2] Philosophie Anatomique, Paris, 1818–22.

membrane. This mucus, according to M. Saint-Hilaire, is always met with in the stomach and intestines of the fœtus; and the presence of meconium, and of other excrementitious matters in the intestines, shows, that digestion must have taken place. This digestion he considers to be effected upon the mucus, secreted in the manner just mentioned; and, in support of its being inservient to sanguification, he affirms, that its quantity is too great for the simple purpose of lubricating the parts; that mucus is the first stage of all organic compounds; that it predominates in all young beings; is the foundation of every organ; is more capable of assimilation than any other substance, &c. But independently of the whole of this view being entirely hypothetical, it cannot be esteemed probable, that the fœtus is nourished by one of its own secretions. All secretions must be formed from blood. Blood must, therefore, pre-exist in the fœtal vessels, and the process, indicated by M. Saint-Hilaire, be unnecessary. The same objections equally apply to the views of Drs. Lee and Robinson referred to previously (p. 560).

M. Denis made a comparative analysis of the blood of the mother and of the fœtus. He found the latter richer in solid constituents and in blood-corpuscles. The two following analyses were by him—the one of the venous blood of the mother; the other of the placental blood as it flowed from an artery of the cord. The latter was of a brown red colour, smelt of the liquor amnii, and became of a brighter hue on exposure to the air.

	Venous blood of mother.	Blood of umbilical artery.
Water	781·0	701·5
Solid residue	219·0	298·5
Fibrin	2·4	2·2
Albumen	50·0	50·0
Blood-corpuscles	139·9	222·0
Peroxide of iron	0·8	2·0
Phosphuretted fat	9·2	7·5
Osmazome and cruorin	4 2	2·7
Salts	12·5	12·1[1]

Allusion has already been made to the opinions of Schreger on fœtal nutrition. These were developed in a letter, written by him, in 1799, to Sömmering.[2] He considers that all communication of nutritious matter between the mother and fœtus takes place through lymphatics which he has described as existing in considerable numbers in the placental and umbilical cord. The red blood flowing in the maternal vessels is too highly charged with carbon, and with other heterogeneous substances, he thinks, to serve for the nutrition of the fœtus. Its serous part, which is purer and more oxygenized, is therefore alone exhaled. The uterine arteries pour this serum into the spongy texture of the placenta, whence it is taken up by the lymphatics of the fœtal portion. These convey it along the umbilical cord to the thoracic duct, whence it passes into the left subclavian, vena cava superior, right

[1] Simon's Animal Chemistry, by Day, Sydenham Society edition, i. 238, London, 1845.

[2] Epistol. ad S. Th. Sömmering, De Functione Placentæ Uterinæ, Erlang., 1799. See, also, Richerand, op. cit., 13ème édit. § ccvi.

auricle and ventricle, ductus arteriosus, and aorta; and, by the umbilical arteries, is returned to the placenta. In this course, it is mixed with the blood, and becomes itself converted into that fluid. When it attains the placenta, the blood is not poured into the cells of that organ to be transported to the mother, but passes into the umbilical vein, the radicles of which are continuous with the final ramifications of the umbilical arteries. Lateral pores, however, exist in the latter, which suffer fluids to escape, that cannot be elaborated by the fœtus, or that require again to be submitted to the maternal organs, before they are fitted for its support. These fluids, according to Schreger, are not absorbed by the veins of the uterus, but by the lymphatics of that viscus, which are so apparent in the pregnant state, and have been injected by Cruikshank, Meckel, &c. In his view, therefore, the conversion of the serous fluid into blood is chiefly effected in the lymphatic system; and it has been a favourite hypothesis with many physiologists, that organs, regarding whose functions we are so profoundly ignorant, and whose developement is so much greater during intra-uterine than extra-uterine existence,—as the thymus, and thyroid glands, and the supra-renal capsules,—are, in some way, connected with the lymphosis or hæmatosis of the fœtus. We have already referred to the conjectures, that these organs are diverticula for the blood of those parts the functions of which are not exerted until an after period of existence. M. Broussais[1] makes the thyroid a diverticulum to the larynx; the thymus to the lungs, and the supra-renal capsules to the kidneys. Notwithstanding these ingenious speculations, our darkness, with regard to the true functions of these singular organs, is considerable.

To conclude.—The most plausible opinion we can form on this intricate subject is, that the mother secretes the substances, which are placed in contact with the fœtus, in a condition best adapted for its nutrition; that in this state they are received into the system, by absorption, as the chyle or the lymph is received in the adult,—undergoing modifications, in their passage through the fœtal placenta, as well as in every part of the system where the elements of the blood must escape for the formation of the various tissues.

With regard to the precise nutritive functions executed in the fœtal state,—and 1, as concerns *digestion*,—it is obvious, that this cannot take place to any extent, otherwise excrementitious matter would have to be thrown out, which, by entering the liquor amnii, would be fatal to its important functions, and probably to the very existence of the fœtus. Yet that some digestion is effected is manifest from the presence of meconium in the intestines, which is probably, in part, the excrementitious matter arising from the digestion of the mucous secretions of the alimentary canal.

2. *Respiration*, as accomplished by lungs, does not exist; and we have already seen, that the idea of the fœtus possessing the kind of respiration of the aquatic animal is inadmissible. An analogous function to the respiration of the adult, however, exists as respects the

[1] Commentaires des Propositions de Pathologie, &c., Paris, 1829, or Drs. Hays's and Griffith's translation, p. 214, Philad., 1832.

changes effected upon the blood. It is probable, that blood is sent to the placenta to be there aerated, as it is in the lungs in extra-uterine life. Such was the opinion of Sir Everard Home, of Girtanner, Stein,[1] and we may say it is that of many of the most enlightened physiologists of the day. The chief arguments brought forward in support of it are,—the absolute necessity for aeration to every living being, animal or vegetable; the no less necessity to the life of the fœtus of a free circulation of blood along the umbilical cord to and from the placenta; and the analogy of birds, in which the umbilical vessels are inservient to respiration by receiving the external air through the pores of the shell, so that if the shell be greased, respiration is prevented, and the chick dies.[2]

The sensible evidences of these changes being accomplished by the placenta are not like those we possess regarding the aeration of the blood in its passage through the lungs of the adult, where the venous differs so essentially from the arterial blood. It is indeed asserted, in works of anatomy, that "the effete blood of the umbilical arteries becomes regenerated in the placenta, assumes a brighter hue, and is returned to the fœtus by the umbilical vein;" but this is not in accordance with experiment and observation. Bichat[3] made numerous dissections of young pigs whilst yet in utero, and uniformly found the blood of the arteries and veins presenting the same appearance, and resembling the venous blood of the mother. Not the slightest difference was observed between the blood of the aorta and that of the vena cava, or between that of the carotid artery and of the jugular vein. He made the same observations in three experiments of a similar kind on fœtuses of the dog. He, also, frequently examined human fœtuses that had died in utero, and always found the same uniformity between arterial and venous blood: hence he concludes, that there is no difference between them in the fœtus, at least in appearance. Similar experiments by Autenrieth[4] furnished like results. Dr. Granville, too, affirms, that he has never been able to detect the least difference between the arterio-umbilical and venous-umbilical blood in the many cases he has examined,[5] and it is important to bear this fact in mind, inasmuch as the absence of such difference may be received as one of the evidences that a fœtus has not respired. The apparent identity, however, between the blood passing to the placenta by the umbilical arteries and that returning by the vein cannot be real. The slightest reflection will show, that they must differ, and such is the opinion, from observation, of Messrs. Bostock,[6] Jeffrey,[7] and others. It is from the blood,

[1] Meckel's Handbuch, u. s. w., Jourdan's and Breschet's French translation, iii. 793, Paris, 1825.

[2] Varnishes of organic animal matters, as albumen, gelatin, &c., have no effect in preventing the transmission of air. See Towne, Guy's Hospital Reports, Oct. 1839, p. 385.

[3] Anatomie Générale, ii. 344, Paris, 1818; and Recherches Physiologiques sur la Vie et la Mort, p. 190, Paris, 1806.

[4] Dissertatio Sistens Experimenta circa Calorem Fœtûs, et Sanguinem Ipsius Instituta, Tubing., 1799.

[5] Graphic Illustrations, &c., p. 20.

[6] Op. citat.

[7] Chapman, Philadelphia Journal of the Med. and Phys. Sciences, i. 10.

carried by the umbilical vein and distributed over the body, that all the organs of the fœtus have to derive the materials of their nutrition and developement; and being deprived of these materials, the fluid must necessarily be different in the umbilical arteries from what it is in the umbilical vein. The researches of more modern chemistry have not been directed to the fœtal blood, but M. Fourcroy[1] analyzed it, and found it differ materially from the blood of the child that had respired. He asserts, that its colouring matter is darker, and seems to be more abundant; that it is destitute of fibrin and phosphoric salts, and is incapable of becoming florid by exposure to the influence of atmospheric air. It has been found, too, that the corpuscles of fœtal blood do not resemble those of the blood of the mother. The fact, however, of the similarity in appearance between the arterial and venous blood of the fœtus is no evidence that respiration is not one of the fœtal functions, inasmuch as the same thing is observed in fishes. Under the head of Circulation it was remarked, that the coloration of the blood is perhaps of no farther importance than as indicating, that the vital change of aeration has taken place in the lungs. In this case, we have the vital change effected without any such coloration. Yet how, it may be asked, is the modification in the blood produced where no placenta and no umbilical cord exist? as well as in the cases before referred to in which the fœtus continues alive for hours after the death of the mother? And can we suppose that in such cases aeration is effected by the liquor amnii containing an unusual quantity of oxygen, as has been presumed by some physiologists? We have before remarked, that Professor J. Müller was unable to detect oxygen in the liquor amnii, and found that when fish were placed in it, they died as soon as in oil.[2] These are embarrassing questions,—more easily propounded than answered. By some, it has been presumed, that the liver, even in the adult, performs a function supplementary to that of the lungs; and the great size of the organ, in the fœtus, has been conceived to favour the idea, that it may separate carbon and other matters freely from the system, and in this way, be depuratory; but the grounds for this presumption are not, we think, impregnable.

3. It is in the *fœtal circulation*, that we observe the most striking peculiarities of intra-uterine existence. Of its condition at the very earliest periods we know little that is not conjectural. We will, therefore, consider it as it is effected during the last months of utero-gestation. From the sketch already given of the circulatory organs of the fœtus, it will be recollected,—1st. That the two auricles of the heart communicate by an aperture in the septum, called *foramen ovale*, which has a valve opening towards the left ventricle. 2dly. That near the orifice of the vena cava inferior is the *valve of Eustachius*, so situate as to direct the blood of the cava into the foramen ovale. 3dly. That the pulmonary artery has a vessel passing from it into the aorta,—the *ductus arteriosus*. 4thly. That two arteries, called *umbilical*, proceed from the internal iliacs to the umbilicus and placenta; and lastly, That the *umbilical vein* from the placenta pours part of its blood into the

[1] Annales de Chimie, vii. 165.

[2] Op. citat., i. 305.

vena porta; and part passes by the *ductus venosus*,—a fœtal vessel,—into the inferior cava. The course of the circulation, then, is as follows. The blood of the umbilical vein,—the radicles of which communicate with those of the umbilical arteries in the placenta,—proceeds along the vein to the umbilicus, and thence to the liver. A part of this traverses the ductus venosus, enters the vena cava inferior, and becomes mixed with the blood from the lower parts of the fœtus: the remainder passes into the vena portæ, is distributed through the liver, and, by means of the hepatic veins, is poured into the vena càva. In this manner it attains the right auricle. Owing to the arrangement of the valve of Eustachius, the blood passes immediately through the foramen ovale into the left auricle,—without being mixed with that proceeding from the upper parts of the body,—into the right auricle through the vena cava superior. The left auricle is consequently as much developed as the right, which it would scarcely be did it receive only the blood from the lungs. Were it not as large, it is obvious, that it would be insufficient to carry on the circulation when the whole of the blood passes through the lungs, and is poured into it, after respiration is established.

Such are the opinions of Wolff and Sabatier[1] regarding the use of the Eustachian valve. According to this view, if the valve did not exist, the aerated blood, conveyed to the heart by the ductus venosus, instead of being directed into the left auricle through the foramen ovale, would pass into the right auricle, and thence, in part, at least, into the right ventricle; from which it would be transmitted, through the pulmonary artery and ductus arteriosus, into the descending aorta; so that no part of the body above the opening of the duct into the aorta could receive aerated blood, whilst much of that which passes along the aorta would be returned to the placenta by the umbilical arteries. But as the blood is directed into the left auricle by the Eustachian valve, it passes thence into the left ventricle, and by it is forced into the aorta, which distributes it to every part of the system, and thus conveys the regenerated fluid to every organ. Dr. Wistar[2] suggested, that, without this arrangement of the Eustachian valve, the coronary arteries, distributed to the heart, would be unfit for supporting the life of that organ, inasmuch as they would be deprived of a regular supply of revivified blood. From the left auricle, the blood passes into the left ventricle, and from the left ventricle into the ascending aorta, and to the upper parts of the body, from which it is brought back, by the vena cava superior, into the right auricle; thence it is transmitted into the right ventricle, and, by the contraction of the ventricle, into the pulmonary artery. By this vessel the greater part is sent through the ductus arteriosus into the descending aorta, and a small part to the lungs. From the lungs, it is returned into the left auricle by the pulmonary veins. Through the descending aorta, the blood, conveyed in part by the ductus arteriosus, and in part by the contraction of the

[1] Traité Complet d'Anatomie, ii. 224, and iii. 387; and Memoir. de l'Academ. des Sciences pour 1744.

[2] System of Anatomy, 3d edit., edited by Dr. Horner, ii. 76, Philad., 1823.

left ventricle, is distributed, partly to the lower extremities, from which it is returned by corresponding veins into the vena cava inferior, and partly by the umbilical arteries to the placenta.

This view of the circulation supposes—what is disputed—that the blood of the vena cava superior and vena cava inferior does not undergo admixture in the right auricle; whence it would follow that some parts of the body receive a purer blood than others,—the upper parts, as the head and neck, receiving that which flows immediately from the placenta, whilst the lower do not obtain it until it has circulated through the upper. Under any view it is manifest, that not the whole of the blood is distributed to the organ of aeration, as in the adult, but a part only, as in the batrachia.

Bichat and Magendie[1] contest the explanation of Wolff and Sabatier regarding the use of the valve of Eustachius and the non-admixture of the blood of the two cavæ in the right auricle. In their opinion, the two bloods do commingle; but—owing to the existence of the foramen ovale, and the arrangement of the valve of Eustachius—the left auricle is filled simultaneously with the right; and, consequently, the same kind of blood must be distributed to both the upper and lower portions of the body. The uses of the foramen ovale and ductus arteriosus are explained as follows. As the left auricle receives but little blood from the lungs, it could furnish only a small quantity to the left ventricle, did it not receive blood through the foramen ovale; and again, as the lung is exerting no function during the state of fœtal life, the blood is sent along the pulmonary artery and ductus arteriosus into the aorta, so that the contraction of both ventricles is employed in propelling the blood along the aorta to the lower parts of the body and the placenta. Without this union of forces, it is conceived, the blood could not be urged as far as the placenta.

Experiments by Dr. John Reid[2] favour the views of Wolff and Sabatier. He took a fœtus of about seven months, and threw simultaneously a red-coloured injection up the vena cava inferior, and a yellow-coloured one down the vena cava superior. On tracing the red injection upwards, it was found to have passed through the foramen ovale, and to have filled the left side of the heart, without any intermixture with the yellow, except very slightly at the posterior part of the right auricle. Not a drop of the yellow appeared to have accompanied the red to the left heart. From the left heart it ascended the aorta, and filled all the large vessels going to the head and upper extremities. The injection, in all these vessels, had not the slightest tinge of yellow. On tracing the yellow injection downwards, he found it filling the right auricle and ventricle, whence it proceeded along the pulmonary artery, and filled the ductus arteriosus, and the branches proceeding to the lungs. On entering the aorta, it passed down that vessel, filling it completely without any admixture of red, so that all the branches of the thoracic and abdominal aorta were filled with the yellow. From this and other experiments of a similar kind, Dr. Reid infers, that the

[1] Précis Elémentaire de Physiologie, 2de édit. ii. 550, Paris, 1825.
[2] Edinb. Med. and Surg. Journ. xliii. 308.

blood, returning from the placenta, passes principally to the head and upper extremities; and that the lower part of the body is chiefly supplied by blood returning by the vena cava superior; or, in other words, by blood that has already gone the circuit of the body. The observations, however, of Dr. T. Williams[1] have convinced him, notwithstanding the opposing experiments of Dr. Reid, that the Eustachian valve is mechanically inefficient in preserving the individuality of the two currents from the vena cava as they traverse the right auricle; and he affirms, that at the period of its diastole, when the auricle has attained a moderate distension, it may be readily demonstrated, that the two streams must intermingle freely. Hence it is not true—he infers—that the difference of quality, between the blood distributed to the two portions of the body of the fœtus, is as great as is generally taught by anatomists.

After all, the great difference between the adult and the fœtal circulation is,—that in the former, a part of the blood only proceeds to the organ of sanguification; that the aerated blood is poured into the right auricle instead of the left; that, instead of proceeding through the lungs, a part of the blood gets at once to the left side of the heart, whence it is sent to the head and upper extremities, and the remainder goes directly from the pulmonary artery into the aorta; and that a part of the aortic blood proceeds to the lower extremities, and the remainder goes to the placenta, from which it is returned into the inferior cava.

4. With regard to the *nutrition*, (properly so called,) of the fœtus, it is doubtless effected in the same manner as in the adult; and our ignorance of the precise nature of the mysterious process is equally great. During the whole of fœtal existence, it is energetically exerted; and especially during the earlier periods. Sömmering has asserted, that the growth of the fœtus fluctuates; that it is greatest in the first month; in the second, less; in the third, greater; less, again, in the fourth; and again greater until the sixth, when it diminishes until birth.

There is a singular circumstance connected with the nutrition of the fœtus, that cannot be passed over without a slight notice, although, in its details, it belongs more properly to pathological anatomy. Owing to inappreciable causes, the different parts of the fœtus, or some particular part, may be preternaturally developed, or be defective, so as to give rise to *anomalies* of conformation, or what have been termed *monstrosities—vitia primæ conformationis.* Three kinds of monsters may be considered to exist. The *first* comprises such as are born with an excess of parts, as with two heads to one trunk, two trunks to one head; with four arms and four legs; twins with a band uniting them, as in the case of the Siamese twins, &c. The *second* includes those in which parts are defective, as acephali, anencephali, &c.; and the *third*, those in which there is perversion of the formative process, so as to produce various modifications in the direction and situation of organs,—as where the heart is on the right side, the liver on the left, &c.; in other words where there is *transposition of the viscera*. In these cases

[1] London Med. Gaz., March 31, 1843.

there is respectively—to use the language of the German pathologists —*superabundant*, *defective*, and *perverted* action of the force of formation—the Bildungstrieb—to which we have more than once alluded.

The hypotheses, that have been advanced to account for these formations, as well as for those in which the parts are irregularly developed, may be reduced to three,—others, that have been hazarded, having no probability in their favour. *First*. They have been attributed to the influence of the imagination of the mother on the fœtus in utero. *Secondly*. To accidental changes experienced by the fœtus at some period of uterine existence; and *Thirdly*. To some original defect or fusion of the germs. The first of these causes has been a subject of keen controversy amongst physiologists, at all periods. We have seen, that the mother transmits to the fœtus materials for its nutrition; and that, to a certain extent, nutrition is influenced by the character of the materials transmitted; so that if these be not of good quality or in due quantity, the fœtus may be imperfectly nourished, and even perish. Any violent mental emotion may thus destroy the child, by modifying the quantity or quality of the nutritive matter sent to it. Small-pox, measles, and other contagious diseases can be unquestionably communicated to the fœtus in utero; so that its life is indirectly but largely dependent upon the condition of the mother; and many striking examples of the influence of the mother on the constitution of her unborn babe are given by Dr. Combe.[1] But the maternal influence has been conceived to extend much beyond this; and it has been affirmed, that her excited imagination may occasion an alteration in the form of particular parts of the fœtus, so as to give rise to *nævi*, and to all kinds of *mother's marks*, as they have been termed. These may consist of spots resembling raspberries, grapes, &c.; or there may be defective formation of particular parts,—and some of the cases that have been brought forward in favour of their having been induced by impressions, made upon the mother during pregnancy, are sufficiently striking. There are numerous difficulties, however, in the way of accepting the cause assigned. If a child has been born with nævi of any kind, the recollection of the mother is racked to discover whether some event did not befall her during gestation to which the appearance may be referred, and it is not often difficult to discover plausible means of explanation. Cases have occurred in which the mother, when a few months advanced in pregnancy, had been shocked by the sight of a person who had lost a hand, and the child has been born with the same defect. A young female, a few months gone with child, visited a brother in one of the hospitals of London, who was wounded in the side. His condition affected her extremely. Her child was born with a deep pit in the same part that was wounded in the brother. These are samples of the thousands of cases that have been recorded. Similar instances have been related of the inferior animals. In the extracts from the minute book of the Linnean Society of London, an account is

[1] Treatise on the Physiological and Moral Management of Infancy, Amer. edit., p. 67, Phila., 1840.

given, by Mr. George Milne, F. L. S., of the effect of the imagination of a cat on her young. One afternoon, whilst Mr. Milne and his family were at tea, a young cat which had arrived at the middle of gestation, was lying on the hearth. A servant, by accident, trod very heavily on her tail; she screamed violently, and from the noise emitted, it was evident, that a considerable degree of terror was mingled with the feeling from the injury. From so common a circumstance no extraordinary result was expected; but, at the full time, she dropped five kittens, only one of which was perfect: the other four had the tail remarkably distorted; and all in the same manner.[1]

Are we to consider these and similar cases of malformation or monstrosity to be dependent upon the influence of the maternal imagination on the fœtus in utero? Or are we to regard them as coincidences, the cause being inappreciable, but such as gives occasion to vicious organization, where no coincidence with excited imagination can be discovered? Under the head of Generation we have shown the difficulty in believing, that the mother's fancy can have any effect—as to sex or likeness—during a fecundating copulation. Let us, then, inquire what we have to admit in a case where a female is, we will suppose, four months advanced in pregnancy, when she is shocked at the appearance of one who has lost his arm, and the child is born with a like defect. It has been seen, that the communication between the mother and fœtus is of the most indirect kind; that the circulation of the fœtus is totally distinct from that of the mother; and that she can only influence the fœtus through the nutritive material she furnishes—whatever be its character,—and, consequently, that such influence must be exerted on the whole of the fœtus, and not on any particular part. Yet, in the case we have assumed, the arm must have been already formed, and the influence of the mother's fancy have been exclusively exerted upon its absorbents, so as to cause them to take up that which had been deposited!

This assumed case is not environed with more difficulty than any of the kind. It is a fair specimen of the whole. Yet how impracticable to believe, that the effect can be connected with the assigned cause, and how much more easy to presume that the coincidence has been accidental. Cases of hair-lip are perpetually occurring, yet we never have the maternal imagination invoked as the cause; because it is by no means easy to discover a similitude between the affection and common extraneous objects. Moreover, in animals of all kinds—even in the most inferior, as well as in plants—monstrous formations are incessantly occurring where maternal imagination is out of the question. As a cause of monstrosity, therefore, its influence has been generally regarded as an inadmissible hypothesis, and by many has been esteemed ridiculous; yet it manifestly receives favour with Sir Everard Home;[2] and Professors Elliotson[3] and Burdach[4] appear inclined to favour it; but on the whole we are justified in adopting the opinion of

[1] Fleming's Philosophy of Zoology, vol. i. Edinb. 1822.
[2] Philos. Transactions for 1825, and Lect. on Compar. Anat., v. 190, Lond., 1828.
[3] Translation of Blumenbach's Physiology, 4th edit., p. 497, Lond., 1828.
[4] Die Physiologie als Erfahrungswissenschaft, B. ii.

Dr. Blundell, which has been embraced by Drs. Allen Thomson[1] and Wagner,[2] that it is contrary to experience, reason, and anatomy, to believe that the strong attention of the mother's mind to a determinate object or event can cause a determinate or specific impression upon the body of her child, without any force or violence from without; and that it is equally improbable, that, when the imagination is operating, the application of the mother's hand to any part of her own body, will cause a disfiguration or specific impression on a corresponding part of the body of the child. The third hypothesis, with regard to defective germs, has been canvassed under the head of Generation, and deemed insufficient. The second, consequently, alone remains, and is almost universally adopted. Independently of all disturbing influences from the mother, the fœtus is known to be frequently attacked with spontaneous diseases, as dropsy, ulceration, gangrene, cutaneous eruptions, &c. Some of these affections occasionally destroy it before birth. At other times, it is born with them; and hence they are termed *connate*, or *congenital*. The following table, drawn up by Mr. Wilde[3] from the records of the Gebäranstalt, of Vienna, exhibits the malformations observed in 23,413 births.

Clubfoot,	16 cases,	or once in		1463·31
Hare lip,	20	"	"	1170·65
——— simple,	9	"	"	2601·44
——— with cleft palate,	11	"	"	2128·45
Spina bifida,	5	"	"	4682·6
Hydrocephalus,	6	"	"	3902·16
Six fingers,	3	"	"	7804·33
Imperforate anus,	2	"	"	11706·5
Hemicephalia,	1	"	"	23413
Acephalia,	1	"	"	23413
Umbilical hernia,	1	"	"	23413
Without eyes,	2	"	"	11706·5
Wanting superior part of vertex,	1	"	"	23415
Lenticular cataract,	1	"	"	23413
Wanting one upper extremity,	2	"	"	11706·5
With plurality of fingers and toes,	5	"	"	4682·6
Hydrocephalus with spina bifida, and closed anus,	1	"	"	23413
Clubfoot and closed anus,	1	"	"	23413

In a population, consequently, chiefly illegitimate, 88 deviations from the natural type occurred in 23,413 births, or about 1 in every 266 cases.

According to the last census of the United States, (1840,) the proportion of deaf and dumb amongst the whites was 1 in 2123; amongst the coloured, 1 in 2933.[4]

Where a part has been wanting, the nerve, or bloodvessel, or both, proceeding to it, have likewise been found wanting; so that the defect of the organ has been thus explained; without our being able, however, to account for the deficiency of such nerve or bloodvessel; which is the main point.

1 Art. Generation, Cyclop. of Anat. and Physiol., P. xiii., p. 477, February, 1838.
2 Elements of Physiology, translated by Dr. Willis, p. 227, note, Lond., 1841.
3 Austria, &c., p. 224, Dublin, 1843.
4 Tucker, Progress of the United States in Population and Wealth in Fifty Years, p. 77, New York, 1843.

In some cases of monstrosity, a fusion of two germs seems to have occurred. Two vesicles have been fecundated and subsequently commingled, so that children have been produced with two heads and one trunk, or with two trunks and one head, &c. &c. This is one mode of accounting for the whole class of monsters by excess, including those commonly called *double monsters;* but it can scarcely be presumed, that the slighter cases of monstrosity by excess,—six fingered children, for example—are produced by the fusion of germs;—and, accordingly, Professor Vogel[1] ascribes them to the "*furcation* of a single germ," and Professor Vrolik[2] is in favour of the view of excess or irregular distribution of developmental power, and prefers to regard those cases "as examples rather of singleness tending to duplicity than of duplicity tending to singleness;" and the reasons he assigns for this view, and for rejecting the hypothesis of fusion, are:—"that it is probable, that the whole class of monsters by excess owe their origin to different degrees of one common fault, and, consequently, that the explanation of their origin ought to be the same for all;—that no kind of fusion can account for the production of supernumerary individual organs, the rest of the body being single; but that it is not impossible, that excess of power in the ovum, which, all admit, can alone explain the lower degrees of duplicity, may, in proportionally higher degrees, perhaps by the formation of two primitive grooves, produce the more complete double monsters, or even two such separate individuals as are sometimes found within a single amnion."

Bischoff[3] refers monstrosities with the number of parts in excess to various causes. *First*, to original formation of the germ. *Secondly*, to an uncommonly energetic developement of an originally single germ, induced probably by external causes. *Thirdly*, to an *ovum in ovo;* and *fourthly*, to arrest of developement.

This interesting department of pathological anatomy has become, of late years, of moment as elucidating the normal formation of the animal body, which appears to be effected—even in the production of anomalies—in accordance with a unity of organic composition, and with laws of developement but little appreciated until the present century, and still sufficiently obscure. The labours of Geoffroy and Isidore Saint-Hilaire, Serres, Sömmering, Meckel, Tiedemann, Béclard, Gurlt, Breschet, Allen Thomson, Vrolik, and others, have—as Cuvier remarked of some of them—occasioned the accumulation of an infinity of facts and views, which, even if we do not admit all that their authors contend for, cannot fail to be of solid advantage to science.

5. The *animal temperature* of the fœtus cannot be rigorously determined. The common belief is, that it is some degrees lower than that of the mother; and it is affirmed, that the temperature of the dead fœtus is higher than that of the living. If such be the fact, it must possess means of refrigeration. M. Edwards found, in his experiments,

[1] The Pathological Anatomy of the Human Body, translated by Dr. Day, p. 509, Lond.. 1847.

[2] Art. Teratology, Cyclopædia of Anatomy and Physiology, Pt. xxxviii., p. 976, Feb. 1850.

[3] Art. Entwickelungsgeschichte mit besonderer Berücksichtigung der Missbildungen, in Wagner's Handwörterbuch der Physiologie, 6te Lieferung, s. 914, Braunschweig, 1843.

that the temperature of new-born animals is inferior to that of the adult; which is in accordance with the general belief regarding that of the fœtus in utero. In some cases, as in those of the kitten, puppy, and rabbit, if the young be removed from the mother, and exposed to a temperature of between 50° and 70°, the temperature will sink,—as happens to the cold-blooded animal,—to nearly the same degree. He found the faculty of producing heat to be at its minimum at birth; but it progressively increased, until in about fifteen days the animal acquired the power in the same degree with the adult. This was not the case, however, with all the mammalia. It seemed to be confined to animals that are born blind; in which a state of imperfection probably exists in other functions. It was the same with birds as with mammalia: birds, hatched in a defective state, as regards their organs generally, have the power of producing heat defective; whilst others, born in a more perfect condition, have the organs of calorification more capable of exercising their due functions. In a case in which the mother, who had borne five children, was confident that her period of gestation was less than 19 weeks, but probably from the length and weight of the fœtus it was 25 weeks, the power of calorification of the latter was so low, that artificial heat was constantly needed to sustain it: under the influence of the heat of the fire, however, it evidently became weaker, whilst the genial warmth of a person in bed rendered it lively and comparatively strong.[1]

Opinions with regard to the temperature of the human infant vary. Haller[2] asserts that it has less power of producing heat than the adult, and such is the opinion of MM. Despretz, Edwards,[3] and the generality of physiologists. The latter gentleman estimated it at 94·25° of Fahrenheit. On the other hand, Dr. John Davy[4] affirms, that the temperature of young animals generally, and that of a new-born child, which he particularly examined, was higher than that of the adult. It is impossible to account for this discordance; but the general results of experiments would seem to agree with those of M. Edwards. Howsoever this may be, the fœtus certainly possesses the power of producing its own caloric; otherwise its temperature should correspond with that of the mother, which, we have elsewhere seen, is not the fact.

6. That the fœtal *secretions* are actively formed is proved by the circumstance, that all the surfaces are lubricated nearly as they are afterwards. The follicular secretion is abundant, and at times envelopes the body with a layer of sebaceous matter—*vernix caseosa*—of considerable thickness. Vauquelin and Buniva[5] have asserted, that this is a deposit from the albumen of the liquor amnii; but it is not found except on the body of the fœtus. It is not on the placenta or umbilical cord, and is most abundant on those parts of the fœtus, where the follicles are most numerous. Fat also exists in quantity after the fifth month. The greatest question has been in regard to the presence

[1] Edinb. Medical and Surgical Journal, vol. xi.
[2] Element. Physiol., vi. 3.
[3] De l'Influence des Agens Physiques, Paris, 1824.
[4] Philos. Transact. for 1814, p. 602.
[5] Annales de Chimie, tom. xxxiii.; and Mémoir. de la Société Médicale d'Emulation, iii. 229.

of certain secretions that are of an excrementitious character. For example,—by some, the *urinary secretion* is supposed to be in activity from the earliest period of intra-uterine existence, and its product to be discharged into the liquor amnii. Such is the opinion of Meckel.[1] The circumstances that favour it, are,—the fact of the existence of the kidneys at a very early period; and that at the full time the bladder contains urine, which is evacuated soon after birth. On analysis, this is found to be less charged with urea and phosphoric salts than afterwards. Of the *meconium*, we have already spoken (p. 560). It is manifestly an excretory substance, produced, probably, by the digestion of the fluids of the alimentary canal, mixed with bile. Some, indeed, are of opinion, that it is altogether a secretion from the liver, and intended to purify the blood sent from the mother, so as to adapt it for the circulation of the fœtus. Into the value of the theory on which this notion rests, we have inquired at some length. The notion itself scarcely requires further comment.

c. *Functions of Reproduction.*

These require no consideration. They are inactive during the fœtal state, except that the testicles and mammæ appear respectively to secrete a fluid which is neither sperm nor milk, and is found in the vesiculæ seminales in the one case, and the lactiferous ducts in the other. It would appear also, as before remarked, that ovarian vesicles are already existent at this early period.

[1] Handbuch, u. s. w.; or French translation by Jourdan and Breschet, iii. 780; or the English translation by S. A. Doane, Philad., 1832.

BOOK IV.

CHAPTER I.

AGES.

UNDER this head we have to include the modifications that occur in the functions from birth until dissolution. The different ages may be separated as follows:—*infancy*, comprising the period from birth until the second dentition;—*childhood*, that between the second dentition and puberty;—*adolescence*, that between puberty and manhood;—*virility*, that between youth and old age;—and *old age*.

1. INFANCY.

The age of infancy extends from birth to the second dentition, or until about the seventh or eighth year. By M. Hallé, and after him by MM. Renauldin,[1] Rullier,[2] Adelon,[3] and others, this has been subdivided into three periods, which are somewhat distinct from each other, and may therefore be adopted with advantage. The one comprises the period between birth and the first dentition,—generally about seven months; a second embraces the whole period of the first dentition, or up to about two years; and the third includes the interval, that separates the first from the second dentition.

a. *First Period of Infancy.*

As soon as the child is ushered into the world, it assumes an independent existence, and a series of changes occurs in its functions of the most sudden and surprising character. Respiration becomes established, after the manner in which it is to be effected during the remainder of existence; and the whole of the peculiarities of fœtal circulation cease. The first act after the child is extruded is to breathe, and at the same time to cry. What are the agencies, then, by which the first inspiration is effected, and the disagreeable impression made. This has been an interesting topic of inquiry amongst physiologists. A few of the hypotheses that have been indulged will be sufficient to exhibit the directions which the investigation has taken.

Whytt,[4]—whose views were long popular, and still have supporters,—conceived, that before birth the blood of the fœtus is properly pre-

[1] Art. Age, Dictionnaire des Sciences Médicales.
[2] Art. Age, Dict. de Médecine, i. 381, Paris, 1821.
[3] Physiologie de l'Homme, 2de édit., iv. 425, Paris, 1829.
[4] An Essay on the Vital and other Involuntary Motions of Animals, Sect. ix. 109, Edinb., 1751.

pared by the mother; and when, after birth, it no longer receives the necessary supply, an uneasy sensation is experienced in the chest, which may be looked upon as the appetite for breathing, in the same manner as hunger and thirst are appetites for meat and drink. To satisfy this appetite, the brain excites the expansion of the chest to prevent the fatal effects, that would ensue if the lungs were not immediately aroused to action. This appetite is supposed to commence at birth, owing to the circulation being quickened by the struggles of the fœtus, and to an additional quantity of blood passing through the lungs, which excites them to action, and seems to be the immediate cause of the appetite. Haller[1] ascribes the first inspiration to the habit, which the fœtus has acquired, whilst in the uterus, of taking into the mouth a portion of the liquor amnii; and he supposes, that it still continues to open its mouth, after leaving the mother, in search of its accustomed food. The air, consequently, rushes into the lungs, and expands them; the blood is distributed through them, and a regular supply of fresh air is needed to prevent it from stagnating in its passage from the right to the left side of the heart. Dr. Wilson Philip[2] regards the muscles of inspiration as entirely under the control of the will; and he thinks, that they are thrown into action by the uneasy sensation experienced by the infant, when separated from the mother, and having no longer the necessary changes produced upon its blood by her organs. M. Adelon thinks it probable, that the series of developements occurring during gestation predisposes to the establishment of respiration. According to him, the lungs gradually increase in size during the latter months; the branches of the pulmonary vessels become enlarged, and the ductus arteriosus diminished; so that the lungs are prepared for the new function they have to execute. In addition to these alterations, he conceives that the process of accouchement predisposes to the change; that, by the contractions of the uterus, the circulation of the blood must necessarily be modified in the placenta, and, consequently, in the fœtus;—for he is a believer in the doctrine, that the fœtus receives blood from the mother by the placenta. Owing to this disturbance in the circulation, more blood is sent to the lungs; and when the child is born, it is subjected to new and probably painful impressions. "For instance," he remarks, "the external air, by its coldness and weight, must cause a disagreeable impression on the skin of the infant, as well as on the origin of all the mucous membranes; and, perhaps, the organs of the senses being, at the same time, suddenly subjected to the contact of their proper irritants, receive painful impressions from them. These different impressions being transmitted to the brain, are reflected to the different dependencies of the nervous system, and, consequently, to the nerves of the inspiratory muscles; these muscles, thus excited, enter into contraction, in the same manner as the heart is stimulated to renew its contractions during syncope; when a stimulating vapour is inspired."

The view taken by Dr. Bostock[3] explains the process, as far perhaps as is practicable, on mechanical principles. The first respiratory act,

[1] Elem. Physiol., viii. 5, 2.
[2] Quarterly Journal of Science, &c., vol. xiv. 100.
[3] Elementary System of Physiology, 3d edit., p. 323, Lond., 1836.

according to him, seems to be purely mechanical, and to result from the change of position which the child undergoes at birth. From the mode in which it rests in utero, every thing is done that position can accomplish, to diminish the dimensions of the chest; and any change in this position must have the effect of liberating the lungs from a portion of the pressure which they sustain. The head cannot be raised from the breast, nor the knees removed from the abdomen, without straightening the spine; and the spine cannot be reduced to a straight line without elevating the ribs and permitting the abdominal viscera to fall; but the ribs cannot rise nor the diaphragm descend, without enlarging the chest; and, as the chest enlarges, the lungs, which are the most elastic organs of the body, expand their air-cells, hitherto collapsed by external pressure, and the external air rushes in. The same cause is considered to account for the new circulatory movement. The blood, which, in the fœtus, had passed through the foramen ovale and ductus arteriosus without visiting the lungs, is solicited from its course by the expansion of the chest, which draws the blood through the pulmonary artery as forcibly as it does air through the windpipe. The blood, thus exposed to the air in the lungs, becomes arterialized; and, from this moment, the distinction between arterial and venous blood is established. The circulation through the vessels peculiar to the fœtal condition now ceases, even without any ligature being placed upon the umbilical cord.

On the whole, the view of Whytt, with the additions suggested by Dr. Marshall Hall, affords, perhaps, the best explanation of the phenomena. It has been elsewhere shown, that the function of respiration is partly voluntary and partly involuntary; partly, in other words, under the cerebro-spinal, and partly under the reflex system of nerves. When the *besoin de respirer* or appetite for air becomes irresistible, the reflex or true spinal system acts predominantly, and the muscles concerned in the mechanical phenomena of respiration are immediately thrown into appropriate action.

The sudden and important changes supervening in this manner guide us to the decision of an interesting medico-legal inquiry,—whether in a case of alleged infanticide, the child has respired or not;—in other words, whether it was born alive or dead? After respiration has been established, the lungs, from being dark-coloured and dense, become of a florid red hue; are light and spongy, and float on water: on cutting into them, the escape of air from the air-cells occasions a crepitus, and a bloody fluid exudes; there is an approach to closure of the foramen ovale; the ductus arteriosus is empty, as well as the ductus venosus; and the absolute weight of the lungs may be doubled.

The different conditions of the organs of circulation, of the cord and skin, at different periods, beginning at the first and ending with the thirty-fifth day, have been summed up as follows by M. Devergie,[1] from the result of numerous and careful observations. They may enable us to judge approximately of the age of the young infant, in questions of a medico-legal character. On *the first day*. Cord beginning to wither. Foramen ovale, ductus arteriosus, ductus venosus,

[1] Médecine Legale, 2de edit., i. 552, Paris, 1840.

and umbilical vessels open. *Second day.* Withering of the cord complete. Foramen ovale closed in two out of eleven cases; partially closed in one out of seven. Ductus arteriosus beginning to close. Umbilical arteries obliterated to a greater or less extent. Umbilical veins and ductus venosus still open. *Third day.* Desiccation of the cord. Foramen ovale sometimes closed. Ductus arteriosus obliterated in one in eleven cases. Umbilical arteries very often obliterated. Umbilical vein and ductus venosus still open. *Fourth day.* Cord beginning to fall off. Foramen ovale closed in about one-third of the cases. Ductus arteriosus still open in the majority of cases. Umbilical arteries closed, but sometimes open near the iliacs. Umbilical vein and ductus venosus much contracted. *Fifth day.* Separation of the cord with rare exceptions. Foramen ovale closed in more than half the cases. Ductus arteriosus closed in about half the cases. Umbilical vessels closed; vein occasionally open. Separation of the cuticle advanced. *Eighth day.* Entire separation of the cord, with commencing cicatrization. Foramen ovale closed in three-fourths of the cases. Ductus arteriosus completely obliterated in half the cases. Umbilical vessels closed. *Ninth to eleventh day.* Cicatrization of the umbilicus often complete; sometimes, however, there is an oozing of mucus from the cord for many days, so that the cicatrix is retarded. Separation of the cuticle on the trunk, chest, and abdomen, and at the articulations. *Twentieth to twenty-sixth day.* Separation of the greater part of the cuticle. *Thirtieth to thirty-fifth day.* Separation of the entire cuticle, excepting that of the hands and feet, which is often delayed until the *fortieth day.*[1]

Respiration having been once thoroughly established, the individual enters upon the first period of infancy, which has now to engage attention. The animal functions, during this period, undergo considerable developement. The sense of tact is little evinced, but it exists, as the child appears very sensible to external cold. At first, touch is not exerted under the influence of volition; but, towards the termination of the period, it begins to be active. Taste is almost always null at first. M. Adelon[2] thinks, that it is probably exerted on the first day as regards the fluids, which the infant sucks and drinks. We have daily evidence, however, that at an early period of existence, the most nauseous substances, provided they are not irritating, are swallowed indiscriminately, and without the slightest repugnance; but, before the termination of the period under consideration, the taste becomes inconveniently acute, so that the exhibition of nauseous substances, as of medicine, is a matter of more difficulty. Smell is probably more backward than any of the other senses; the developement of its organ being more tardy, the nose small, and the nasal sinuses not in existence. In the first few weeks, sight and hearing are imperfectly exerted, but, subsequently, they are in full activity. The internal sensations, being instinctive, exist; all those at least that are connected with the animal and nutritive functions. Hunger and thirst appear during the first day of existence; the desire of passing the urine and fæces is doubtless

1 Guy, Principles of Forensic Medicine, Part i. p. 149, Lond., 1843.
2 Physiologie de l'Homme, edit. cit., iv. 433.

present, notwithstanding they appear to be discharged involuntarily; and the morbid sensation of pain is often experienced, especially in the intestinal canal, owing to flatus, acidity, &c. During the first part of the period, the child exhibits no mental and moral manifestations; but, in the course of a few weeks, it begins to notice surrounding objects, especially such as are brilliant; and to distinguish between the faces to which it has been accustomed and those of strangers;—awarding a smile of recognition or of satisfaction to the former, a look of gravity and doubt to the latter. Locomotion, as well as the erect attitude, is, at this time, utterly impracticable. The muscular system is not yet sufficiently developed; the spinous processes of the vertebræ are not formed, and it has not learned to keep the centre of gravity—or rather the vertical line—within the base of sustentation. The function of expression, at the early part of the period, is confined to *vagitus* or squalling, which indicates the existence of uneasiness of some kind; but, before the termination of the period, the infant unites smiles and even laughter to the opposite expressions, and attempts to utter sounds, which cannot yet be considered as any effort at conventional language. Sleep is largely indulged. Soon after birth, it is almost constant, except when the child is taking nutriment. Gradually, the waking intervals are prolonged; but, throughout, much sleep is needed, owing to the frail condition of the nervous system, which is soon exhausted by even feeble exertion, and requires intermission of action.

After birth, the child has to subsist upon a different aliment from that with which it was supplied whilst in the womb. Its digestion, therefore, undergoes modification. The nutriment is now the milk of the parent, or some analogous liquid, which is sucked in, in the manner described under Digestion. For this kind of prehension the mouth is well adapted. The tongue is large, compared with the size of the body, and the want of teeth enables the lips to be extended forward, and embrace the nipple more accurately and conveniently. The action of sucking is doubtless as instinctive as the appetite for nutriment, and equally incapable of explanation. The appetite appears to be almost incessant, partly owing to the rapidity of growth, which demands continual supplies of nutriment; and partly, perhaps, to a feeling of pleasure experienced in the act, which is generally the prelude to a recurrence of sleep, broken in upon apparently for the mere purpose of supplying the wants of the system, or the artificial desire produced by frequent indulgence. Often, we have the strongest reason for believing, that the great frequency of the calls of the appetite is occasioned by the habit, with many mothers, of putting the child constantly to the breast; inasmuch as in children that have been trained, from an early period, to receive the nutriment at fixed hours only, the desire may not recur or be urgent until the lapse of the accustomed interval. Digestion, at this age, is speedily accomplished;—the evacuations being frequent,—two or three or more in the course of the day,—of a yellow colour, something like custard, or curdy, and having by no means the offensive smell, which they subsequently possess. During the first days after birth, they are dark and adhesive, and consist of *meconium*. Young mothers are apt to be alarmed at this appearance, which is

entirely healthy, and always exists to a greater or less degree. Respiration is more frequent than in the adult, nearly in the proportion of two to one; and is chiefly accomplished by the muscles that raise the ribs, on account of the great size of some of the abdominal viscera, which do not permit the diaphragm to be readily depressed. The stethoscope exhibits the respiration to be much more sonorous; so characteristic, indeed, is it, in this respect, that by way of distinction it has been called "puerile," and appears to indicate a greater degree of activity in the respiratory function. The circulation is more rapid; —the pulsations at birth being nearly twice as numerous as in the adult. Nutrition is active in the developement of organs. Calorification becomes gradually more and more energetic from the time of birth. The recrementitial secretions, as well as the excrementitial, are as regularly formed as in the adult; but the products vary somewhat. The urine, for instance, is less charged with urea, and contains benzoic acid; and the perspiration is acidulous. M. Adelon[1] asserts, that these excretions are frequently insufficient for the necessary depuration, and that nature, therefore, establishes others, which are irregular and morbid, in the shape of cutaneous efflorescences, &c. These can scarcely be regarded as depurations; unless we consider all cutaneous eruptions, connected with gastric or digestive irritation, to be such, which is more than problematical; especially as most of them are neither pustular nor vesicular, and therefore not accompanied by any sensible exudation.

b. *Second Period of Infancy, or First Dentition.*

This period embraces the whole time of dentition, and is considered to include the age between seven months and two years. In it the external senses are in great activity, and continually furnishing the intellect with the means from without for its developement. The internal sensations are likewise active. From these united causes, as well as from the improved cerebral organization, the intellect is more strengthened during this period than perhaps during any other. The senses are continually conveying information; perception is, therefore, most active,—as well as memory; but imagination and judgment are feeble and limited. The faculty of imitation is strong, so that, by hearing spoken language, and appreciating its utility, the child endeavours to produce similar sounds with its own larynx, and gradually succeeds,—the greater part of its first language consisting of imitations of sounds emitted by objects, and these sounds applied to designate the objects themselves in the manner we have seen elsewhere. The affective faculties are likewise unfolded during this period; but generally those of the selfish cast are predominant, and require careful attention for their rectification. Even at this early time of life, the effect of a well-adapted education is striking, and spares the child from numerous inconveniences, to which unlicensed indulgence in its natural passions would inevitably expose it. The general feeling is, that the infant is not yet possessed of the necessary intelligence to pursue the course indicated;

[1] Physiologie de l'Homme, 2de édit., iv. 436, Paris, 1829.

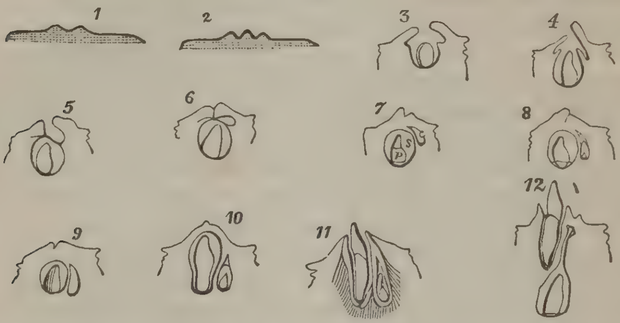
but it is surprising how soon it may be made to understand the wishes of its instructor, and with what facility it may be moulded, at this tender age, in almost any manner that may be desired. During this period the child is capable of standing erect and of walking. Previously, these actions were impracticable, for the reasons already stated, as well as owing to the weight of the thoracic and abdominal viscera,—to the spine having but one curvature, the convexity of which is backwards,—to the small size of the pelvis, and its inclination forwards, so that it scarcely supports the weight of the abdominal viscera, and to the smallness of the lower limbs and the feebleness of their muscles, which are insufficient to prevent the trunk from falling forward. These imperfections are, however, gradually obviated, and the child commences to support itself on all-fours; a position assumed much more easily than the biped attitude, owing to the centre of gravity being situate low, and the base of sustentation large. In this attitude it moves about for some time, or locomotion is effected by pushing a chair before it, or by being steadied by its nurse. Gradually it passes from place to place on its feet, by laying hold of surrounding objects, and, in proportion as the bones and muscles become developed, and the obstacles to progression are removed, it succeeds in walking alone; but is some time before it is capable of running or leaping. Perhaps the average period at which the infant begins to walk is about twelve months; but we see great difference in this respect. When once fairly on its legs, the whole of the waking hours is spent in incessant activity and amusement. The functions of expression are commensurate with the intellectual developement, which, we have seen, is great in this period. Sleep, which is now more interrupted, is still imperiously and frequently demanded,—the nervous system being devoid of the strength it subsequently possesses, and therefore requiring repose.

One of the most important changes going on at this age concerns the function of digestion. This is the process of *dentition*, which usually commences about the seventh month, and continues till the end of the second year at least. Prior to the appearance of the teeth, mastication is of course impracticable; and the food best adapted for the delicate powers of the infant is that afforded by the maternal breast, or a substitute which resembles it as closely as possible. The appearance, however, of teeth would seem to indicate, that the infant is about to be adapted for more solid aliment. About the sixth week of intra-uterine life, a depression or groove, of horseshoe shape, is seen along the edge of the jaw in the mucous membrane of the gum, which is the *primitive dental groove* of Professor Goodsir;[1] and in the second month of utero-gestation, if the jaws be carefully examined, the germs of teeth are perceptible in their substance, under the form of membranous papillæ of an oval shape, attached by their deep-seated extremity to a vascular and nervous pedicle, and by their superficial extremity to the gum; over which follicles are formed by the approach of processes from the sides of this primitive groove. The cavity of these follicles is at first filled with a colourless limpid fluid; but a kind of vascular and nervous

[1] Edinb. Med. and Surg. Journal, vol. li.

papilla or pulp soon forms in it, which commences at the deep-seated portion of the follicle, proceeds towards the other extremity, and ultimately fills it,—the fluid diminishing in proportion to the increase of

Fig. 451.



Schemes of Sections of the Lower Jaw of the Fœtus at different periods, to show the stages of developement of the sac of a temporary incisor and of the succeeding permanent tooth from the mucous membrane of the jaw. (After Goodsir.)

1. The dental groove is formed in the mucous membrane. 2. The groove widens, and has a papilla at the bottom: this is the papillary stage. 3, 4, and 5 represent the follicular stage; the lips of the groove enlarge, and form a sunken follicle, in which the papilla, now enlarged and beginning to acquire the form of the future tooth-pulp, is hid. Membranous opercula, or laminæ, are formed from the sides of the follicle, and, as seen in 5, meet over, leaving a lunated depression behind. The diagram, 5, supposing the opercula to be gently opened out, may be taken to represent a cross section through an incisor follicle. 6. The lips of the groove also meet, except the lunated depression. 7. The opercula and lips of the groove cohere; the follicle becomes a closed sac (*s*); the papilla is the tooth-pulp (*p*), and has the shape of the crown of the future tooth; and the lunated depression becomes a cavity of reserve for the developement of the succedaneous permanent tooth: the saccular stage is now complete. The remaining figures, 8 to 12, show the commencement of the cap of dentine on the pulp, the subsequent steps in the formation of the milk tooth, and its eruption through the gum (11); also the gradual changes in the cavity of reserve, the appearance of its laminæ and papilla, its closure to form the sac of the permanent tooth, its descent into the jaw, behind and below the milk-tooth, and the long pedicle (12) formed by its upper obliterated portion.

the pulp. About the termination of the third month, ossification begins, and a little sooner in the lower than in the upper jaw. This consists, at first, of a deposition of ivory matter on the surface of the pulp and at its top, which goes on increasing in width until it covers the whole of the dental pulp with a shell. It augments, also, in thickness at the expense of the dental pulp, which becomes gradually less and less. When the bony shell has extended as far as the neck of the tooth, the external membrane or sac of the tooth—for the follicle consists of two membranes—attaches itself closely, but not by adhesion, to the part. The inner membrane becomes much more vascular, and the *enamel* is secreted by it. A thickish fluid is observed to be poured out from the inner surface, which is soon consolidated into a dark, chalky substance, and afterwards becomes white and hard. At birth, the coronæ of the incisors are formed; those of the canine are not completed; and the molares have only their tubercles. The root or fang is formed last of all. As ossification proceeds, the corona of the tooth presses upon the gum, a portion of the follicle being interposed, which, as well as the gum, is gradually absorbed and the tooth issues.

The age at which the teeth make their appearance varies. The fol-

lowing table of the average periods, as stated by some of the principal writers on dental surgery, is given by Mr. Tomes.[1]

Authors.	Central Incisors. Months.	Lateral Incisors. Months.	Canines. Months.	1st Molar. Months.	2d Molar. Months.
Fox,	6, 7, 8	7, 8, or 9	17 to 18	14 to 16	24 to 30
	Extreme cases. 4 to 13				
Hunter,	7, 8, 9	7, 8, or 9	20 to 24	20 to 24	20 to 24
Bell,	5 to 8	7 to 10	14 to 20	12 to 16	18 to 36
Ashburner,	7th, lower jaw	9th, upper jaw	16, 17, 18		
	8th, upper jaw	10th, lower teeth	19 or 20		

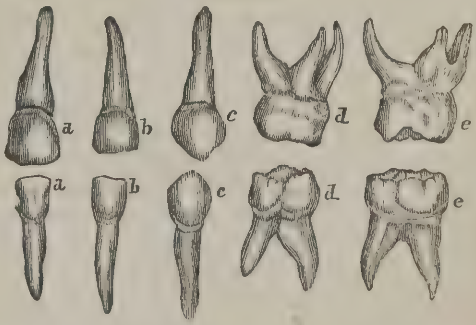
Order of the First Dentition.

Authors.	Incisors. Central.	Incisors. Lateral.	Canines.	Molares. First.	Molares. Second.	
Sir R. Croft,	2	3	7	5	9	Upper jaw.
	1	4	8	6	10	Lower jaw.
Dr. Ashburner,	2	4	6	5	8	Upper jaw.
	1	3	7	5	8	Lower jaw.

Fig. 452.

Front View of the Temporary Teeth.

Fig. 453.



The separate Temporary Teeth of each Jaw.
a. Central incisor. *b.* Lateral incisor. *c.* Canine. *d.* First molaris. *e.* Second molaris.

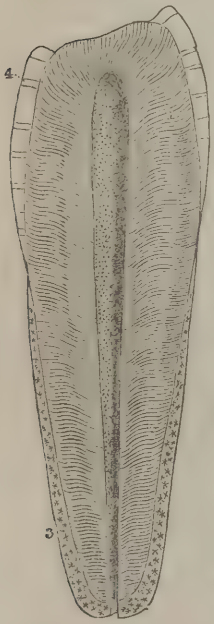
Occasionally, children have been born with teeth, whilst in other cases they have not pierced the gum until after the period we are considering. Generally, the middle incisors of the lower jaw appear about the seventh month, and subsequently those of the upper; next the superior and inferior lateral incisors in succession; then the first lower molares, and first upper; next the inferior and superior canine teeth, successively: and lastly, the second molares of each jaw. As a general rule, the teeth of the lower jaw precede those of the upper: the lateral incisors are, however, an exception, — those of the upper jaw making their appearance, in the majority of cases,

[1] A Course of Lectures on Dental Physiology and Surgery, p. 110, Lond., 1848.

before those of the lower. Where the tooth passes through the dental capsule and integuments, the child is said to have "cut a tooth;" it would seem, however, to be a process of absorption rather than of disruption, as Mr. A. Nasmyth has suggested.[1]

The subject of the intimate anatomy and developement of the teeth has been investigated of late years by many observers, whose contributions are well worthy of study. Amongst the most important are those of Fränkel, Raschkow, Retzius, Arnold, Goodsir,[2] Owen, Nasmyth[3] and Tomes; and an able writer—Mr. Paget[4]—has remarked, that in no organs have the results of recent microscopic researches been so unexpected or brilliant. These researches have shown the teeth to be composed of three main constituents. 1. The *crusta petrosa*, cementum or cortical substance, which differs in its minute structure in no respect from common osseous tissue. It forms the outermost layer of the teeth; visibly surrounds the whole fang, and extends, according to Mr. Nasmyth, in a very thin layer over the enamel of the crown. 2. The *enamel*, or *adamantine substance* which invests only the crown of the teeth, and is composed of solid prisms or fibres about $\frac{1}{5600}$th of an inch in thickness set side by side upright on the ivory; and, 3. The *dentine* or *ivory*, which forms the chief mass and body of the teeth, and is composed of a fibrous basis, traversed by very fine, branching, cylindrical tubuli, which run in an undulating course from the pulp cavity on the interior of which they open, towards the adjacent part of the exterior of the tooth. The basis of the intertubular substance, according to Henle, is composed of bundles of flat, pale, granular fibres, the course of which is parallel to that of the tubules. Mr. Nasmyth,[5] however, states, as the result of his observations, that the so-called tubule is, in reality, a solid fibre, composed of a series of little masses succeeding each other in a linear direction, like so many beads collected on a string.

Fig. 454.



Vertical section of an Adult Bicuspis, cut from without inwards; greatly magnified. (After Retzius.)

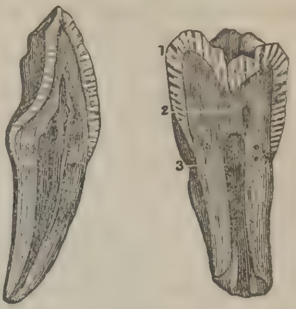
1, 1. Ivory of the tooth, in which are seen the greater parallel curvatures, as well as the position of the main tubes. At the apex of the tooth the tubes are almost perpendicular. 2. Cavity of the pulp, in which are seen, by means of the glass, the openings of the tubes of the dental bone. 3, 3. Cortical substance which surrounds the root up to the commencement of the enamel. 4, 4. Enamel.

Dentition is necessarily a physiological process, but it is apt to be a cause of numerous diseases. The whole period of its continuance is one of great nervous susceptibility,—so that the surgeon never operates during it, unless when compelled; and we can understand, that the pressure exerted by the tooth on the gum, and the consequent inflammation and irritation, may lay the foundation for

[1] Medico-Chirurg. Transactions, vol. xxii., and Op., infra cit., p. 113, Lond., 1849.
[2] Edinb. Med. and Surg. Journ., li.
[3] Researches upon the Developement and Structure of the Teeth, London, 1839 and 1841; and Mr. Robert Nasmyth, in Lond. and Edinb. Monthly Journ. of Med. Sci., Jan. 1843, p. 40.
[4] British and Foreign Medical Review, July, 1842, p. 270.
[5] Op. cit., p. 113, Lond., 1849.

numerous diseases. More are doubtless ascribed to the process than it is entitled to, but still they are sufficiently numerous; and all require in their management the free division of the distended gum, so as to set the presenting part of the tooth at liberty. Whilst the teeth are appearing, the muscular structure of the body is acquiring strength, and the salivary organs are described by anatomists as becoming much more developed. The food of the child is now diversified, and it begins to participate in the ordinary diet of the table. The excrementitious matters are consequently altered in character, particularly the alvine, which become firmer, and acquire the ordinary fæcal smell; the urea is still, however, in the generality of cases, in less proportion than in the adult. The other functions require no special mention.

Figs. 455 and 456.



View of an Incisor and of a Molar Tooth, given by a Longitudinal Section, showing that the Enamel is striated and that the Striæ are all turned to the Centre. The internal Structure is also seen.

1. Enamel. 2. Ivory. 3. Cavitas pulpi.

The number of deaths, during this period, is great. The bills of mortality of London, as has been elsewhere remarked, show, that the deaths, under two years of age, are nearly thirty per cent. of the whole number. In Philadelphia, during a period of twenty years ending with 1826, the proportion was rather less than a third. The cholera of infants is the great scourge of our cities during the summer months, whilst in country situations it is comparatively rare; and it is always found to prevail most in crowded alleys, and in the filthiest and impurest habitations. There is something in the confined and deteriorated atmosphere of a town, which seems to act in a manner directly unfavourable to human life, and to the life of the young especially; and this applies also to the animal. Experiments were instituted by Dr. Jenner, and since by Dr. Baron,[1] which show that a privation of free air and natural nourishment has a tendency to produce disorganization and death. Dr. Baron placed a family of young rabbits in a confined situation, and fed them with coarse green food, such as cabbage and grass. They were perfectly healthy when put up. In about a month, one of them died,—the primary step of disorganization being evinced by a number of transparent vesicles on the external surface of the liver. In another, which died nine days after, the disease had advanced to the formation of tubercles in the liver. The liver of a third, which died four days later, had nearly lost its true structure, so completely was it pervaded by tubercles. Two days afterwards, a fourth died; a number of hydatids was attached to the lower surface of the liver. At this time, Dr. Baron removed three young rabbits from the place where their companions had died to another situation, dry and clean, and to their proper accustomed food. The lives of these were obviously saved

[1] Delineations of the Origin and Progress of Various Changes of Structure which occur in Man, and some of the Inferior Animals, Lond., 1828.

by the change. He obtained similar results from experiments of the same nature performed on other animals.

c. *Third Period of Infancy.*

This requires no distinct consideration;—the growth of the child and activity of the functions going on as in the preceding period, but gradually acquiring more and more energy. Within this period, a third molar tooth appears, which is not, however, temporary, but belongs to the permanent set.

During the whole of infancy, the dermoid texture—skin and mucous membranes—is extremely liable to be morbidly affected; hence, the frequency of eruptive diseases, and of diarrhœa, aphthæ, croup, bronchitis, &c., many of which are of very fatal tendency. Owing, also, to the susceptibility of the nervous system, convulsions, hydrocephalus, and other head affections are by no means unfrequent.

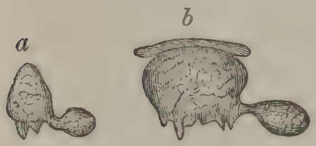
2. CHILDHOOD.

Childhood may be considered to extend from the seventh to the fifteenth year, or to the period of puberty; and it is particularly marked by the *shedding* of the first set of teeth, and the appearance of the second. It is manifest, that in the growth of the jaws with the rest of the body, the teeth, which, for a time, may have been sufficient in magnitude and number, must soon cease to be so; hence, the necessity of a fresh set, which may remain permanently. The process for the formation of the permanent teeth is similar to that of the milk or temporary teeth; yet it presents some remarkable points of difference and affords another surprising instance of the wonderful adaptation of means to definite objects, of which there are so many in the human body.

It is well described by Mr. Thomas Bell,[1] whose opportunities for observation have been unusually numerous, and whose zeal and ability in his profession, as well as in the prosecution of natural science, are well known.

The rudiments of the permanent teeth according to him are not original, and independent, like those of the temporary. They are derived from the latter, and continue, for a considerable time, attached to, and intimately connected with them. At an early period in the formation of the temporary teeth, the investing sac gives off a small process or bud, containing a portion of the essential rudiments, namely, the pulp covered by its proper membrane. This constitutes the rudiment of the permanent tooth. It commences in a small thickening on one side of the parent sac, which gradually becomes more and more circumscribed, and at length assumes a distinct form, though still connected with it by a pedicle. For a time, the new rudiment

Fig. 457.



a. Permanent Rudiment given off from the Temporary in an Incisor.
b. Permanent Rudiment given off from the Temporary in a Molaris. (T. Bell.)

[1] The Anatomy, Physiology, and Diseases of the Teeth, Lond., 1829; 2d Amer. edit., Philad., 1837.

is contained within the same alveolus as its generator, which is excavated by the absorbents for its reception. It is not, according to Mr. Bell, in consequence of the pressure of the new rudiment upon the bone, that this absorption is occasioned, but by a true process of anticipation; for he states, that he has seen, in the human subject—and still more evidently in the foal—the commencement of the excavation before the new sac was formed, and, consequently, before any pressure could have taken place on the parietes of the socket. The absorption does not, indeed, begin in the smooth surface of the socket, but in the cancelli of bone immediately behind it. By degrees, a small recess is thus formed in the paries of the alveolus, in which the new rudiment is lodged, and this excavation continues to increase with the increasing size of the rudiment; whilst, at the same time, the maxillary bone becomes enlarged, and the temporary tooth, advancing in its formation, rises in the socket. The new cell is thus gradually separated from the other, both by being itself more and more deeply excavated in the substance of the bone, and also by the formation of a bony partition between them, as seen in the marginal figure, 458, which exhibits the connexion between the temporary tooth and the permanent rudiment, as it exists after the former has passed through the gum. As the temporary tooth grows and rises in the jaw, the connecting cord or pedicle elongates, and although the sac, from which it is derived, is gradually absorbed, it still remains attached to the neck of the temporary tooth. The situation of each permanent rudiment, when its corresponding temporary tooth has made its appearance through the gum, is deeper in the jaw and a little behind the latter, as represented in the marginal illustrations, (Figs. 459 and 460,) of the upper and lower jaw after the whole of the temporary teeth have passed through the gum. From these, it will be understood, how the upper part of the sac of the permanent rudiment, by means of the cord connected with the gum, gradually assumes the same relation to the gum as was originally sustained by the temporary rudiment.

Fig. 458.

Temporary Tooth and Permanent Rudiment. (T. Bell.)

Such is the view adopted by most odontologists. It is generally believed, that the sacs of the permanent teeth derive their origin from those of the milk teeth. Mr. Goodsir, however, maintains, and with much probability in favor of his view, that the two sets have an independent origin, and that each is developed in a distinct groove, (Fig. 451.) The cavity of reserve in which the permanent teeth are developed having been originally a process of the mucous membrane of the mouth; a rudiment of the communication

Fig. 459.

Temporary Teeth and Permanent Rudiments. (T. Bell.)

subsists even until the eruption of the permanent teeth, under the form of the fibrous cord referred to above, which becomes a *gubernaculum* or guide,—an *iter dentis* or path for the tooth.

The ossification of the permanent teeth, for the incisors and first molaris, commences from the third to the sixth month after birth; about the ninth month, for the canine teeth; about three years, for the second molaris; at three years and a half, for the fourth; and, at ten years, for the fifth; but all this is liable to much variation.

The permanent teeth, during their formation, are crowded together in the jaw; but, as soon as they have advanced to a certain point, and can no longer be contained within their own alveoli, absorption of the anterior parietes of those cavities takes place, and the teeth are allowed to come in some measure forwards. In consequence of such absorption, it frequently happens, that not only the socket of the corresponding temporary tooth, but that of the tooth on each side is opened to the permanent one. Absorption of the root of the temporary tooth,—generally at the part nearest its successor,—now occurs, and this gradually proceeds as the latter advances, until the root is completely removed, when the crown falls off, leaving room for the permanent tooth to supply its place. It does not seem, that this absorption of the root is produced by pressure on the part of the permanent tooth, as it often happens, according to Mr. Bell, that the root of the temporary tooth is wholly absorbed, and the crown falls out spontaneously, long before the succeeding tooth has approached the vacant space. As a general rule, however. the actions must be regarded consentaneous; and Mr. Bell thinks, that this absorption resembles that, already referred to, for the formation of a new cell to receive a permanent pulp, and that it may be termed, like it, a "process of anticipation." In both instances, the existence, though not the pressure, or even the contact, of the new body is necessary to excite the action of the absorbent vessels; and we, accordingly, find that in

Fig. 460.

Temporary Teeth and Permanent Rudiments. (T. Bell.)

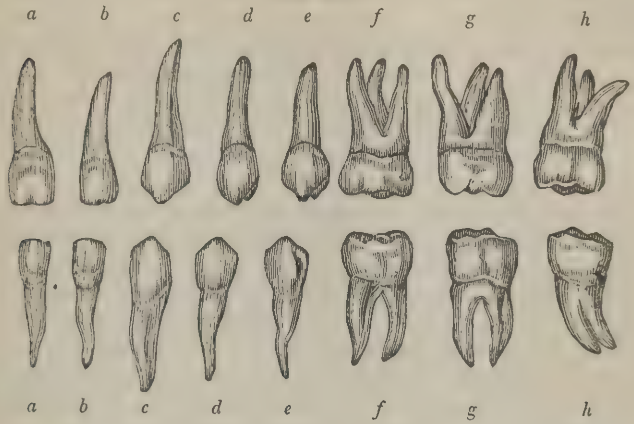
Fig. 461.

Side View of Upper and Lower Jaw, showing the Teeth in their Sockets. The outer Plate of the Alveolar Processes has been taken off.

1. First incisors of upper jaw. 2. First incisors of lower jaw.

those cases, by no means unfrequent, in which the temporary teeth retain their situation in the mouth with considerable firmness until adult age, the corresponding permanent teeth have not been formed.

Fig. 462.



Upper and Lower Teeth.

a, a. Central incisors. *b, b*. Lateral incisors. *c, c*. Canine teeth. *d, d*. First bicuspidati. *e, e*. Second bicuspidati. *f, f*. First molares. *g, g*. Second molares. *h, h*. Third molares or *dentes sapientiæ*.

The following are the periods at which the permanent teeth generally make their appearance.

First molars, - - - - - - -	7th year
Central incisors, - - - - - - -	8th "
Lateral incisors, - - - - - - -	9th "
First bicuspids, - - - - - - -	10th "
Second bicuspids, - - - - - - -	11th "
Canines, - - - - - - - -	12th "
Second molars, - - - - - - -	13th "
Third great molars, *dentes sapientiæ*, - - -	17th to 20th.

When these have all appeared, the set is complete, consisting of thirty-two teeth, sixteen in each jaw,—the number of temporary teeth being only twenty. Fig. 461 represents the upper and lower permanent teeth in their alveoli or sockets, the external alveolar plate having been removed to show the mode in which they are articulated. Fig. 462 represents the same teeth when removed from the socket.

While the jaws are becoming furnished with teeth and increasing in size, they undergo a change of form, and the branches become more vertical, so as to favour the exertion of force during mastication. When the teeth issue from the gums, they are most favourably situate for the act of mastication; the incisors are sharp, the canine pointed, and the molares studded with conical asperities; but, in the progress of age, they become worn on the surfaces that come in constant contact. During the occurrence of these changes, which embrace the whole of the period we are considering, and extend, at times, into the two next, the animal functions, especially that of sensibility, become

surprisingly developed, and the intellectual and moral results of a well adapted system of education strikingly apparent. The nutritive functions are, likewise, performed with energy, the body not yet having attained its full growth; and, towards the end of the period, the organs of reproduction commence that developement, which has to be described presently.

The teeth appear with sufficient regularity to permit an inference to be drawn with regard to the age of the individual, and accordingly it has been proposed by Mr. Saunders[1] to make them a test for age in reference to the children employed in the factories of Great Britain.

3. ADOLESCENCE.

The commencement of this age is marked by one of the most extraordinary developements, which the frame experiences; and its termination by the attainment of full growth in the longitudinal direction. The period of the former of these changes is termed *puberty;* that of the latter the *adult age*. The age of adolescence has been considered to extend from fifteen years to twenty-five, in men; and from fifteen to twenty-one, in women; but this is only an approximation, like the other divisions of the ages, all of which are subject to great fluctuation in individual cases.

During the periods we have considered, no striking difference exists in the appearance of male and female, except as regards the generative organs; but, about the age of puberty, essential changes occur, that modify the characteristics of the two sexes in a manner, which they maintain through the remainder of existence; and these changes affect the whole economy to a greater or less degree. In the male, the skin loses more or less of its delicacy and whiteness; the hair becomes darker; the areolar tissue condensed, and the muscles more bulky, so that they are strongly defined beneath the surface; the beard appears, as well as hair upon the pubes, chest, and in the axillæ. The different parts of the body become developed in such manner that the centre of the frame now falls about the pubes. The encephalon has increased in size, and has become firmer. The ossification of the bones, in the direction of their length, terminates towards the end of the period. The muscles become more red and fibrinous, losing the gelatinous character they previously possessed; and, in the animal, exhibiting those striking changes which we see—from veal to beef, from lamb to mutton, &c. The larynx undergoes great augmentation, and the glottis particularly is elongated and widened. The jaws complete their growth, and the dentes sapientiæ appear so as to make up the full complement of sixteen teeth in each jaw. The changes in the nutritive organs are not great, consisting chiefly in their developement to correspond with the increased size of the frame. The greatest modification occurs in the organs of reproduction, which are now in a state to exercise their important functions. The testicles, at puberty, suddenly enlarge so as to attain twice the diameter they previously possessed;

[1] The Teeth, a Test for Age, considered with reference to the Factory Children, addressed to the Members of both Houses of Parliament, Lond., 1837. See, also, Mr. A. Nasmyth, Researches on the Developement, &c., of the Teeth, p. 159, Lond., 1849.

and the secretion of sperm is accomplished. The penis is also greatly increased in size; and, according to M. Adelon,[1] "becomes susceptible of erection." The susceptibility, however, exists long before this age. It may be noticed even in the first period of infancy. The scrotum assumes a deeper colour. Such are the chief changes that supervene in the male.

In the female, they are not quite so striking;—the general habit remaining much the same as during childhood. The skin preserves its primitive whiteness; and, instead of the areolar tissue becoming more condensed, and the muscles more marked, as in the male, fat is deposited in greater quantity between the muscles, so that the form becomes more rotund. Hair appears on the organs of reproduction and in the axillæ, whilst that of the head grows more rapidly. The developement of the genital organs is as marked as in the male. The ovaries attain double their previous dimensions; the uterus enlarges; and a secretion takes place from it which has been elsewhere described—the *menstrual flux;* the mons veneris and labia pudendi are covered with hair; the labia enlarge and the pelvis has its dimensions so modified as to render labour practicable. At an early age, the long diameter of the brim is from before to behind; but it is now in the opposite direction, or from side to side; and the bosom, which prior to this age, could scarcely be distinguished from that of the male, becomes greatly developed; fat is deposited so as to give the mammæ their rotundity; the mammary gland is enlarged; and the nipple of greater size;—changes fitting the female for the new duties which she may be called on to exercise.

The functions undergo equally remarkable modifications, under the new and instinctive impulse that animates every part of animal life. The external senses attain fresh, and peculiar activity; the intellectual faculties become greatly developed, and this is the period in which the mental character is more improved by education than any other. It embraces, indeed, the whole time of scholastic application to the higher studies. Prior to the end of the period, the male youth enters upon the avocation which is to be his future support, and both sexes may become established in life in the new relations of husband and wife and of parent and child. It is during this age, that an indescribable feeling of interest and affection is experienced between the sexes; and that the boldness of the male contrasts so strikingly with the captivating modesty of the female,—

> "That chastity of look, which seems to hang
> A veil of purest light o'er all her beauties."

The muscles having acquired their strength and spring, the severer exercises are now indulged, and mechanical pursuits of all kinds,—military and civil,—are undertaken with full effect. The expressions participate in the altered condition of the mental and moral manifestations, and indicate vivacity, energy, and enthusiasm. The voice of the male acquires a new character, and becomes graver, for reasons assigned elsewhere; whilst that of the female experiences but slight

[1] Physiologie de l'Homme, 2de édit., iv. 448, Paris, 1829.

modification. The nutritive functions of digestion, absorption, and respiration experience little change; but nutrition, strictly so called, is evidently modified, from the manifest difference in the developement and structure of the various organs. The muscles contain more fibrin; the blood is thicker and richer in red corpuscles; and the excretions manifest a higher degree of animalization. Urea has taken the place of benzoic acid in the urine; and the cutaneous transpiration has lost its acidulous smell, and become rank and peculiar. Lastly, the sexual functions are now capable of full and active exercise, and appear to be intimately connected with the energy and developement of many parts of the economy. If the genital organs do not undergo the due change at puberty, or if the testes of the male or the ovaries of the female be removed prior to that age, considerable changes occur. These are more manifest in the male, inasmuch as the ordinary changes, that supervene at puberty, are in him more marked than in the female. The removal of the testicles, prior to puberty, arrests those changes. The beard does not appear, nor the hair in the axillæ nor on the pubes, as in the entire male; and if those animals in which the males are distinguished by deciduous horns, as the stag,—or by crests and spurs, as the cock, be castrated before their appearance, such appendages do not present themselves. If, however, they be castrated after puberty, they retain these evidences of masculine character. The eunuch, likewise, who becomes such after the appearance of the beard, preserves it, although to a less extent than usual. The developement of the larynx is arrested by castration, so that the voice retains, with more or less change, the treble of the period prior to puberty; hence this revolting operation has been had recourse to for the sake of gratifying the lovers of music.

In the course of age, we find that, during the progressive evolution of the organs, one set is liable to morbid affections at one period, and a different set at another. In early age, the mucous membranes and the head are especially liable to disease; and, at the period we are now considering, affections of the respiratory organs become more prevalent. It is indeed the great age for pulmonary consumption,—that fatal malady, which, Sydenham supposed, destroys two-ninths of mankind. In the female, whose proper feminine functions do not appear at the due time, or are irregularly exercised, the commencement—indeed the whole of this period—is apt to be passed in more or less sickness and suffering.

4. VIRILITY, OR MANHOOD.

M. Hallé has divided this age into three periods,—*crescent*, *confirmed*, and *decrescent virility*. The *first* of these extends from twenty-five to thirty-five in the male, and from twenty-one to thirty in the female; the *second* from thirty-five to forty-five in the male, and from thirty to forty in the female. Neither of these will require remark, the whole of the functions throughout this work,—when not otherwise specified,—being described as accomplished in manhood. Owing to the particular evolution of organs, the tendency is not now so great to morbid affections of the respiratory function. It is more especially the age for cephalic and

abdominal hemorrhage; accordingly, apoplexy and hemorrhoidal affections are more frequent than at any previous period.

In *decrescent virility*,—in which M. Hallé comprises the period of life between forty and fifty in the female, and between forty-five and sixty in the male,—signs of decline are manifest. The skin becomes shrivelled and wrinkled; the hair is gray, or white and scanty; the teeth are worn at the top, chipped, loose, and many perhaps lost. The external senses, especially the sight, are more obtuse, partly owing to a change in the physical portions of the organ, so that powerful spectacles become necessary, and partly owing to blunted nervous sensibility. Owing to the same cause, the intellectual faculties are exerted with less energy and effect, and the moral manifestations are more feeble and less excitable. Locomotion is less active, owing to diminution in the nervous power, as well as probably to physical changes in the muscles, so that the individual begins to stoop,—the tendency of the body to bear forwards being too great for the extensor muscles of the back to counteract. The expressions participate in the condition of the intellectual and moral acts, and are consequently, less exerted than in former periods. The nutritive functions do not exhibit any very remarkable change, and may even remain active to a good old age. The functions of reproduction show the greatest declension, especially in the female. The male may preserve his procreative capabilities much longer than this period; but in the female the power is usually lost, the loss being indicated by the cessation of menstruation. After this, the ovaries shrivel, the uterus diminishes in size; the breasts wither; the skin becomes brown and thick; long hairs appear on the upper lip and chin, and all the feminine points are lost that were previously so attractive. The period of the cessation of the menses is liable to many different disorders, which are the source of much annoyance, and are, at times, attended with fatal consequences. Prior to their total disappearance, they often become extremely irregular in their recurrence, sometimes returning every fortnight; debilitating by their frequency, and by the quantity of the fluid lost, and laying the foundation for uterine or other diseases of a serious character. Cancerous affections of the mammæ or labia, which had been previously dormant or not in existence, now appear, become developed, and at times with extreme rapidity. In consequence of the great liability to such affections, this has been called the *critical age*, *critical period* or *critical time of life* or *turn of life*. The danger to the female is not, however, so "critical" at this period as the epithet might suggest,—the statistical researches of M. de Chateauneuf and of Lachaise, Finlaison,[1] and others having shown, that between the ages of forty and fifty no more women die than men. M. Constant Saucerotte has, indeed, attempted to show by statistics on a great scale, that the mortality amongst women is greater between thirty and forty than between forty and sixty; and Muret, in his Statistics of the Pays du Vaud, did not find

[1] Reports on the Evidence and Elementary Facts on which the Tables on Life Annuities are Founded, Lond., 1829.

between forty and fifty a more critical period than between ten and twenty.[1]

5. OLD AGE.

This is the age when every thing retrogrades. It is the prelude to the total cessation of the functions, where the individual expires—which is but rarely the case,—from pure old age. This period has been divided into three stages:—*incipient* or *green old age*, reaching to seventy years; *confirmed old age* or *caducity*, to eighty-five years; and *decrepitude*, from eighty-five years upwards.

In *incipient* or *green old age*, the declension that had occurred in the period of *decrescent virility*, is now more evident. The intellectual and moral manifestations exhibit more marked signs of feebleness; and the muscular powers totter, and require the aid of a support—as well to convey a part of the weight of the body to the ground, as to enlarge the base of sustentation. The muscles of the larynx participate in the general vacillation; the

> "Big manly voice,
> Turning again towards childish treble, pipes
> And whistles in the sound,"

and is broken and tremulous.

The appetite is great, and the powers of digestion are considerable; but mastication is largely deteriorated. In the first place, the teeth fall out, in consequence of the constant deposition of fresh layers in the dental cavities, which ultimately close them, and obliterate the vessels that pass to the internal papillæ for their nutrition. As soon as the teeth have fallen out, the alveolar processes, which supported them, waste away by absorption, and the depth of the jaw is thus greatly lessened. On these accounts, the jaws only approach each other at the forepart; the chin projects, and the angle of the jaw is thrown more forward. As the teeth and the sockets disappear, the alveolar margins become thin and sharp, and the gum hardens over them; the chin and nose necessarily approach (Figs. 463 and 464); the lips fall in, and the speech is inarticulate. We can thus understand the peculiarities of the mastication of the aged. They are compelled to bite with the anterior portions of the jaws; for which reason, as well as owing to the greater obliquity of the insertion of the levator

Fig. 463.

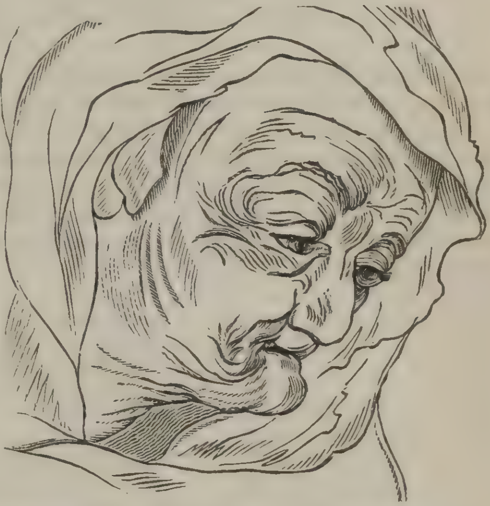
Skull of the Aged. (After Sir C. Bell.)

[1] Churchill, Outlines on the Principal Diseases of Females: American Medical Library edit., p. 82, Philad., 1839; or Professor Huston's Amer. edit., Philad.

muscles of the lower jaw, but little force can be exerted; and owing to the too great size of the lips, the saliva cannot be retained. Respiration is not as readily accomplished, partly owing to the complete ossification of the cartilages of the ribs, but chiefly to diminished muscular powers. The valves of the heart and many of the bloodvessels, especially of the extremities, become more or less ossified, and the pulse is somewhat slow and intermittent, but generally perhaps faster than in the adult. Of 255 women between the ages of 60 and 96 examined by MM. Hourmann and Dechambre,[1] the average number of pulsations in the minute was 82·29; of respirations, 21·79. Nutrition is effected to such a degree only as to keep the machine in feeble action; and animal heat is formed to an inadequate extent, so that the aged require the aid of greater extraneous warmth: in many cases, the powers of reproduction in the male are completely lost.

In *confirmed old age*, the debility of the various functions goes on augmenting. The mental and corporeal powers almost totter to their fall; and frequently a complete state of dementia or dotage exists. Often, however, we are gratified to find full intellectual and moral enjoyment prevailing even after this period, with the possession of considerable corporeal energy. The author had the honour to enjoy the friendship of three illustrious individuals of this country, two of whom had filled the highest office in the gift of a free people, all of whom are now no more; each of these gentlemen exhibited, after the lapse of eighty-two summers, the same commanding intellectual powers and the same benevolence that ever distinguished them.

Fig. 464.



Physiognomy of the Aged. (After Sir C. Bell.)

In this stage, locomotion becomes more difficult; the appetite is considerable, and the quantity eaten at times prodigious,—the digestive powers being incapable of separating the due amount of chyle from a quantity of aliment that was sufficient in the previous ages. Difficulty, however, sometimes arises in defecation, the muscular powers being insufficient to expel the excrement. From this cause, accumulations occasionally take place in the rectum, which may require the use of mechanical means,—as injections, the introduction of an

[1] Archiv. Général. de Médec., 1825.

instrument to break them down, &c. Generation is, usually, entirely impracticable, erection being impossible; and during the whole of this and the next stage, the urinary organs are liable to disorder—irritability about the neck of the bladder, and incontinence of urine, being frequent sources of annoyance.

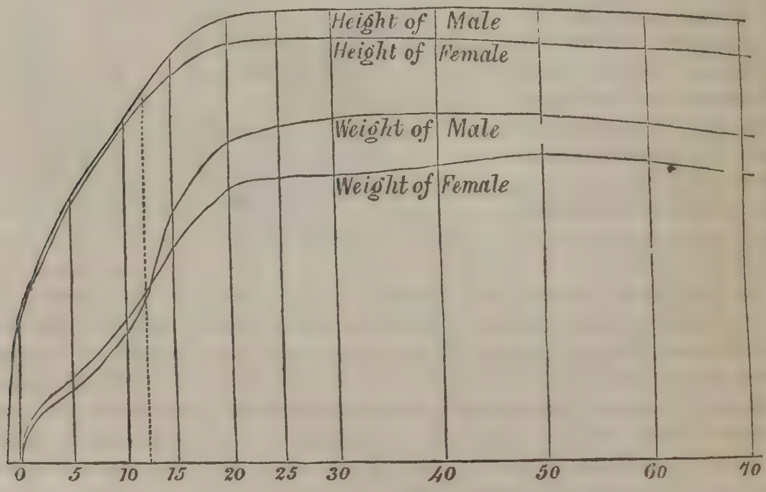
The density of the lungs, together with the quantity of blood they admit, diminishes with the progress of age; the thorax itself is gradually accommodated to the change; it becomes atrophied as the lungs are atrophied; it contracts as they contract, and the diminution in their vascularity, which is always in a ratio with the diminution of structure, shows the direct proportion between the weakened chemical power and diminished mechanical forces. (Magendie, and MM. Hourmann and Dechambre.)

Finally, to this stage succeeds that of *decrepitude*, so well described by Shakspeare:—

> "Last scene of all,
> That ends this strange, eventful history,
> Is second childishness, and mere oblivion;
> Sans teeth, sans eyes, sans taste, sans everything."
>
> As You Like It, ii. 7.

The loss of power, mental and corporeal, becomes progressively greater; and, in addition to the abolition of most of the external senses—especially those of sight and audition—the intellectual faculties are, perhaps, entirely gone; all muscular motion is lost, and paralysis requires constant confinement to the bed, or easy chair; the excretions are passed involuntarily; sensibility becomes gradually extinct, and life finally flits away as imperceptibly as the twilight merges in the shades of night.

Fig. 465.



Curves indicating the Developement of the Height and Weight of Male and Female at Different Ages. (Quetelet.)

M. Quetelet[1] has deduced from extensive observations the relative heights and weights of both sexes at different periods of existence. The results are exhibited in the diagram. (Fig. 465.) The increase in height is most rapid in the first year, and afterwards diminishes very gradually: between the ages of 5 and 16, the annual increase is very regular. The difference between the height of the male and female at birth continues to augment during infancy and growth; but it is not very marked until about the 15th year, after which the female grows at a diminished rate; whilst the male goes on in nearly the same degree until about the age of 19. The female, consequently, arrives at her full height earlier than the male;—the full height of the latter not being generally attained until about the age of 25. At about 50, both sexes experience a diminution of stature, which continues during the latter part of existence. The average height of the male and female who have attained their full developement is about 3¼ times that of the new-born infant of the sexes respectively. The relative weight of the sexes corresponds pretty nearly with the height. The preponderance exhibited by the male at birth increases gradually during the first few years; but towards the period of puberty the proportional weight of the female increases; and about the age of 12 there is little difference between the sexes. After this, however, the weight of the male increases much more rapidly, especially between 15 and 20: subsequently, there is not much increase on the part of the male, although his maximum is not attained until the age of 40; whilst there is an absolute diminution on the part of the female, whose weight remains less during nearly the whole period of child-bearing. After this, however, her weight again experiences an increase, and its maximum is attained about 50. In old age, the weight of both sexes undergoes a diminution in nearly the same degree. The average weight of the male and female who have attained their full developement is twenty times that of the new-born infant of the sexes respectively.

Such is a brief description of the chief changes that befall the body in the different ages. To depict them more at length would be inconsistent with the object and limits of this elementary work. It is clear, that, although the divisions, which we have adopted from Hallé, are entirely arbitrary,—must run into each other, and be liable to numerous exceptions,—certain well-marked changes occur about the commencement or termination of many of them, and a singular diversity takes place in the successive evolution of organs: whilst some are predominant at one time, they fall behind others at a previous or subsequent period; and such changes may lay the foundation for morbid affections in certain organs at one age, which do not prevail at another. The ancients, who believed that great mutations occur at particular intervals,—every three, seven, or nine years, for example, as the particular number might be at the moment in favour,—compared these periods to knots uniting the different stages of life, and giving the

[1] Annales d'Hygiène Publique, vi. 89; and in his work, Sur l'Homme et le Développement de ses Facultés, Bruxelles, 1835; or translation of the same, p. 63, Edinb., 1842.

economy a new direction. These knots they called the *climateric* or *climacteric years*, and they conceived the body to be especially liable to disease at the periods of their occurrence. The majority assigned them to the number seven and its multiples; and the fourteenth and twenty-first years especially were conceived to be replete with danger. Others applied the term *climacteric* to years resulting from the multiplication of seven with an odd number, and especially with nine; the sixty-third year being regarded, by almost all, as the *grand climacteric*. The error with the ancients lay in considering that numbers exerted any agency. Every one admits the influence of particular evolutions on health; and, at the present day, the word *climacteric* is generally restricted to certain periods of life, at which great changes supervene, independently of any numerical estimate of years;—such as the period of puberty in both sexes;—that of the cessation of the menses or the critical time of life in the female, &c.

It need hardly be remarked, that the different ages described, instead of extending through the protracted period of eighty-five years and upwards, may be varied by original constitution, climate, habits of life, &c., so that the stages may be shorter than usual, and all the signs of decrepitude occur many years earlier; and, on the other hand, the period of decrepitude may, through strength of original conformation, and other causes, be largely postponed.

CHAPTER II.

SLEEP.

The difference between the two classes of animal and nutritive functions is strikingly exhibited in the phenomena we have now to consider. Whilst the former are more or less suspended, the latter continue their action with but little modification. The functions of sensibility, voluntary motion, and expression cannot be indulged for any length of time, without fatigue being induced, and a necessity arising for the reparation of the nervous energy expended during their action. After a time,—the length of which is somewhat influenced by habit,—the muscles have no longer power to contract, or the external senses to receive impressions; the brain ceases to appreciate; mental and moral manifestations are no longer elicited; the whole of the functions of relation become torpid, and remain in this state until the nervous system has been renovated, and adapted for the repetition of those functions, which, during the previous waking condition, had been exhausted. This state constitutes *sleep;* which, consequently, may be defined—the periodical and temporary suspension of all, or most, of those functions that connect us with the universe. The suspension occurs in those functions and in those only; and hence the consideration of sleep, in many physiological treatises, has immediately followed that of the functions of relation. The nutritive functions continue regularly in action from the earliest period of fœtal formation; before mental manifestations exist in the embryo, and during sleep. For them there is no cessation, and

scarcely any declension of activity, until the decadency of the frame affects them along with the whole of the machinery. Sleep, in the language of poetry, has been compared to death; and Dr. Good[1] has stated, that the resemblance between them is not less correct upon the principles of physiology, than it is beautiful among the images of poetry. "Sleep is the death or torpitude of the voluntary organs, while the involuntary continue their accustomed actions. Death is the sleep or torpitude of the whole." Physiologically, the difference appears to us considerable. During the whole of sleep a process of renovation is going on in the organs of animal life, which adapts them for subsequent activity, and contrasts signally with the state of annihilation that constitutes death; hence the important difference between healthy sleep, and the state of coma induced by any morbid cause, from which the patient is aroused languid and exhausted, instead of active and recruited. The fœtus in utero is described by some as in a perpetual sleep, until aroused by the new actions established at birth; but even in this case there must be alternations of activity and suspension in the nervous functions. We have seen elsewhere, that they are manifestly more or less exerted during intra-uterine existence; nervous energy must therefore be expended; and renovation,—to a much less extent, it is true, than in the new-born child,—be necessary. Linnæus,[2] under the term *somnus plantarum*, comprehends a peculiar state in the constitution of many plants during the night, as evinced by a change of position, generally a drooping or folding together of their leaves or leaflets; such a change being occasioned by the withdrawal of the stimulus of light, and, probably, it has been conceived, constituting a state of rest to their vital functions; but it is obvious, that there can be no similitude between this condition and that of the sleep of animals, which is confined to the functions of relation,—functions that do not even exist in the vegetable.

The approach of sleep is indicated by signs, that are unequivocal, and referable to the encephalon. The great nervous centre of animal life feeling the necessity for rest and renovation, an internal sensation arises in it, as well as in the whole of the nervous system over which it presides, termed *sleepiness* or the *sensation* or *want* or *desire of sleep*, which, provided the waking state has been protracted, ultimately becomes irresistible, and often draws on sleep in spite of every effort to the contrary. It is affirmed, that boys, exhausted by exertion, dropped asleep amid the tumultuous noise of the battle of the Nile; and the fatigued soldier has often gone to sleep amid discharges of artillery. An engineer has been known to fall asleep within a boiler whilst his fellows were beating it on the outside with their heavy hammers. Noises will at first prevent sleep, but the desire is ultimately so invincible, that they cease to produce any effect. In the noisy inns of large towns, where the perpetual arrivals and departures of travellers keep up an incessant din and confusion, sleep may be for a time withheld, but it ultimately supervenes, although the tumult may be even tenfold;

[1] Book of Nature, 3d edit., ii. 203, Lond., 1834.
[2] Amœnitat. Academ., tom. iv.

and if the noise should, from any cause, suddenly cease, the individual will probably awake. It is reported of the proprietor of some vast iron-works, who slept close to them, notwithstanding the noise of sledge-hammers, forges, and blast-furnaces, that he would immediately awake if any interruption occurred during the night. This effect of habit is seen in the infant, which has been accustomed to the cradle. The moment the motion and noise of the cradle, or the sound of the nurse's voice—if she has been in the custom of singing the child to sleep—ceases, it awakes.

When the desire for sleep sets in vigorously, the animal functions become more obtuse, until they progressively fail to be exerted. The cessation does not occur in all simultaneously. The power of volition is gradually lost over the muscles; the eyes cannot be kept open; the upper eyelid falls, and if we attempt to raise it again, it appears to be weighed down; the eyeball is directed upwards, and the pupil is contracted; the arms fall where gravity would take them; the extensor muscles of the back, deprived of volition, cease to contract, and the head falls suddenly forward, occasioning *nodding*, which rouses the brain to momentary action, to be again lost, however. If the individual be in the erect attitude, his limbs bend under him; and if sitting, the head gradually falls upon the chest; the extensors of the trunk no longer contract with sufficient force to obviate its tendency to fall forwards; and the attitude, unsupported, cannot be maintained. The same gradual suspension occurs in the muscular movements concerned in speech and in the production of voice, which becomes feeble, confused, broken, and ultimately lost. In short, all the strictly voluntary muscles have their action suspended,—the levator palpebræ superioris among the rest; and the eye is closed by the action of the orbicularis palpebrarum, which is under the reflex system of nerves.

If we determine to resist the desire for sleep, we yawn and stretch, for reasons elsewhere assigned, and endeavour to arouse the functions to renewed activity. If the state of wakefulness has not been long protracted, we may be successful; but all our endeavours fail, if the nervous system be so far exhausted as to render reparation indispensable. From the commencement of sleepiness, the action of the senses is enfeebled, and gradually suspended. The sight yields first,—the closure of the eyelids preventing the organ from being impressed by its special irritant. Smell yields after taste; hearing after smell; and lastly, touch sleeps; although the appropriate irritants may continue to reach the organs of those senses. All the internal sensations, hunger, thirst, &c., as well as the morbid sensation of pain, are no longer appreciated. The intellectual and moral manifestations exhibit from the commencement of the feeling of heaviness the languor that pervades the frame. The will gradually ceases to control the functions under its dominion, until ultimately the power of volition is lost. In the less perfect kind of sleep or in *slumber*, the ideas flit in a disorderly manner, constituting a kind of delirium; but when sleep is complete, the whole encephalic organ appears to be at rest, and perceptions are no longer accomplished: special irritants may be applied to the external senses, but they excite no sensation. Many physiologists affirm, that the

internal functions of nutrition acquire more energy during sleep; but M. Broussais[1] properly disputes the affirmation, and maintains, that the want of action in the senses, muscles, and intellect, must necessarily occasion diminished energy in the nutritive functions. During sleep, circulation and respiration appear to be retarded; perspiration is less active, and digestion more tardy than in the waking condition. The difference in the last respect is so great, that, as M. Broussais remarks, the appetite recurs many hours before the usual time where long watching is indulged, and an additional meal becomes necessary; proving the truth of the old French proverb,—"*qui dort dine*"—"who sleeps dines." Secretion, nutrition, and calorification are also less energetically performed than usual. Absorption alone, according to some, is more active; but there seems not to be sufficient reason even for this assertion. The notion of the greater activity of the nutritive organs is as old as Hippocrates, and has been acquiesced in by almost all subsequent writers without examination, especially as it seemed to show a kind of alternation and equipoise between the respective periods of activity of animal and organic life.

If we examine into the condition of the nervous system during sleep, we find, that the division, which presides over sensation, volition, and the mental and moral manifestations—the animal functions, or those of relation, in other words—has its action temporarily suspended; whilst the vital and nutritive functions that are carried on under the reflex and sympathetic systems never sleep;—respiration, a phenomenon of reflex nervous action, never rests from the commencement of existence to its final cessation. The body generally remains in a state of semiflexion, the one which, as we have elsewhere seen, requires least natural effort. To this, however, there are numerous exceptions depending upon habit. Perhaps the easiest position for the body is on the back. It is that assumed in extreme debility, when the prostration is so great that the individual sinks down in the bed like a dead weight; but the extensor muscles of the thigh and leg, under such circumstances, become fatigued; and relief is obtained by drawing the feet upwards so as to elevate the knees. This is a common attitude in the most debilitating maladies, and is often maintained until within a short time prior to dissolution.

Sleep can persist with the exercise of certain muscles. Couriers, on long journeys, nap on horseback; and coachmen on their boxes. The author has seen a servant boy erect and asleep in the intervals between the demand for his services at table. During the first sleep, the suspension of the animal functions is most complete; but, towards morning, some of them become less asleep, or more excitable than others. The intellectual and moral faculties are frequently inordinately active, giving occasion to dreams, which, with some individuals, occupy a great portion of the period allotted to rest. The sense of tact, too, is easily roused. If we lie in a position that is disagreeable, it is soon changed; the limbs are drawn away, if irritated in any manner; the bedclothes are pulled up, if the air be disagreeably cold, &c. The sense of sight

[1] Op. citat., p. 183.

and the voluntary motions are least readily aroused; so that those functions, which fall asleep the last, are most easily awakened, and they gradually resume their activity in the order in which they lost it. After six or eight hours of sleep,—more or less according to circumstances,—the individual awakes, not generally at once, however; a state of slumber, like that which preceded sleep, now succeeding it. The organs, which are the last to resume their activity, require to be excited to the performance of their functions. The eyes are rubbed; stretching is indulged, which recalls the nervous influx to the muscles; and sighing and yawning arouse the muscles of respiration; and compensate, in some measure, for the minor degree of aeration of the blood accomplished during sleep. The urine is discharged, and the phlegm, which may have collected in the air-passages, is expectorated: these excretions accumulate during sleep, because, owing to diminished sensibility, the call for their evacuation is not as urgent. In cases of catarrh accompanied by copious mucous secretion, and in phthisis pulmonalis, the fluid collects in surprising quantity in the air-passages during sleep, and is expectorated as soon as the brain is sufficiently aroused to respond to the sensation.

When the individual is fully awake, the energy with which the animal functions are exercised exhibits that the nervous system must have entirely recruited during its state of comparative inaction. The period of sleep, necessary for this purpose, varies in different individuals, and at different ages. Some require eight or ten hours; others not more than three or four; and others are said to have been contented throughout the course of a long life with not more than one or two. Men of active minds, whose attention is engaged in a series of interesting employments, sleep much less than the lazy and listless. General Pichegru informed Sir Gilbert Blane,[1] that in the course of his active campaigns he had, for a whole year, not more than one hour of sleep, on an average, in the twenty-four hours. Frederick of Prussia and Napoleon are said to have spent a surprisingly short time in rest; but with respect to the latter, the fact is controverted by one,[2] who had excellent opportunities for observation. It is probable, that in these cases the sleep is more intense, and that such of the animal functions as indispensably require rest are completely suspended during the whole period assigned to it. These are the functions of voluntary motion more particularly; the intellectual and moral faculties requiring a much shorter period of repose, as is manifest by their incessant activity during dreaming,—a condition which, with some, continues through almost the whole night. The same individual, too, will spend a shorter time in sleep, when strongly interested in any pursuit, than in the monotonous occurrences of ordinary life, and, when any subject occupies us intently, it will frequently keep us awake in spite of ourselves; but although the period of sleep may be protracted much beyond the accustomed hour by unusual excitement, the effect of the stimulus becomes insufficient, and sleep comes on under circumstances, which appear most unfavourable to it.

[1] Medical Logic, 2d edit., p. 83.

[2] Bourrienne, Private Memoirs of Napoleon Bonaparte, Amer. edit., Philad., 1831.

The lunatic affords us a wonderful example of powerful resistance to sleep and fatigue, or rather of the short period, which is necessary for the renovation of the nervous system, kept almost incessantly upon the stretch, as it is in many of these distressing cases. In like manner, the sufferer from ill health, loss of property or kindred, resists at times the recurrence of sleep to a degree that excites surprise; and according to a recent writer[1] this want of sleep is the most frequent and immediate cause of insanity: on the other hand, a distinguished physiologist[2] regards too prolonged sleep as the cause of idiocy or madness. It has been a common remark, that women require more sleep than men, and M. Georget[3] assigns them a couple of hours more,—allotting to men six or seven hours, and to women eight or nine; but Dr. Macnish[4] judiciously doubts, whether the female constitution requires more sleep than the male: at least, he says, it is certain, that women endure protracted wakefulness better than men, "but whether this may result from custom is a question worthy to be considered." The fact is, however, too general to allow custom to be invoked. It would seem, indeed, that the female frame, although far more excitable than that of the male, is longer in having that excitability exhausted, and that the recuperative powers are greater, so that when exhausted, it is more readily restored. The notion, that the female needs more rest than the male, appears to be traditionary, and like most traditions, to have been handed down from one individual to another without due examination. The degree of muscular and mental exertion, to which the male is accustomed, would seem to indicate that a longer period of rest ought to be required by him to admit of the necessary restoration of excitability. In infancy and youth, where the animal functions are extremely active, the necessity for sleep is greatest; in mature age, where time is more valued and cares are more numerous, it is less indulged; whilst the aged may be affected in two opposite ways; they may be either in a state of almost constant somnolency, or their sleep may be short and light.

Sleep has been divided by the physiologist into *complete* and *incomplete.* The former is characterized by a suspension of all the animal functions;—a state, the existence of which has been doubted by many. Certain it is, that it can occur but rarely, and only when all the organs have stood in equal need of rest and renovation; and when none have preserved, from the preceding state of waking, a peculiar susceptibility for action. The nearest approach to it occurs in the first hours of repose; after which, it becomes incomplete: some of the functions are not equally sound asleep, and consequently respond to excitants with different degrees of facility; and the various organs do not require the same time for reparation, and therefore awake at different intervals; hence dreams arise, which occur chiefly towards morning, or after the sleep has become incomplete; that is, when some of the animal functions are more or less actively, but irregularly exercised.

1 Brigham, American Journal of Insanity for April, 1845, p. 319.
2 Magendie, Précis de Physiologie, vol. ii., Paris, 1825.
3 De la Physiologie du Systême Nerveux, &c., Paris, 1821.
4 Philosophy of Sleep, Amer. edit., p. 280, New York, 1834.

1. DREAMS.

Anciently, dreams were regarded as supernatural phenomena, under the control of the children of Somnus or Sleep,—Morpheus, Phobetor or Icelos, and Phantasos. These three children, according to Ovid,[1] were capable of transforming themselves into any shape; the employment of Morpheus being to counterfeit the forms of men; Phobetor imitated the likeness of brutes and objects of terror; and Phantasos that of inanimate creatures. For a long time dreams were supposed to reveal future events by types and figures; as when Hecuba dreamed she had conceived a firebrand, and Cæsar that he should lie with his mother; which was interpreted that he should enjoy the empire of the earth,—the common mother of all living creatures. Oneiromancy was an encouraged art, and ministered largely to the credulity and superstition of the people. Strange to say, there are yet those who look upon dreams to be typical and instructive, and consequently supernatural! Mr. Baxter[2] and Bishop Newton openly maintained this doctrine. They divided dreams into two kinds,—good and evil,—and conceived that two kinds of agents, good and evil spirits, are concerned in their production: they consequently accounted for the one or the other sort of dreams, according as the one or the other kind of agents obtain a predominancy![3] It is not necessary to combat these views, —which ought of course to be as applicable to animals as to man,— especially as they are discarded. Dreaming is now properly considered to be an irregular action of the brain, in which the agency of the great controlling power of the will is suspended, and memory and imagination are allowed unlimited sway, so that the most singular and heterogeneous ideas are formed,—still kept, however, somewhat in train by the force of association. At times, indeed, this influence is so great, that every part of the dream appears to go on in the most natural and consistent manner. We witness scenes that have occurred during our waking hours; and seem to see, hear, walk, talk, and perform all the ordinary offices of life. The mind reasons, judges, wills, and experiences all the various emotions. Generally, the whole process is confined to the brain; but, at times, the muscles are thrown into action, and the expression of the feelings and emotions occurs as in the waking state. The dreamer moves, speaks, groans, cries, sings, &c., and if the dream concerns the generative function, the external organs respond, and emission takes place in the male to such an extent, occasionally, as to constitute a true disease, or to be the cause of such,—the *paroniria salax* of Dr. Good,[4] *gonorrhœa dormientium* or *night pollution* of others. During the prevalence of a passion, too, the nutritive organs, in which its effects are experienced whilst awake, may be equally concerned during sleep. The respiration is short and interrupted; and sighs, groans, or laughter, according to the character of the emotion, are elicited; the heart beats with more or less violence; and this state of excite-

[1] Metamorphos., xi. v. 592 ad 645.
[2] An Inquiry into the Nature of the Human Soul, &c., Lond., 1730.
[3] Good, op. cit., p. 194.
[4] Physiological System of Nosology, cl. iv., ord. 1, gen. v., sp. 3.

ment continues after the individual has been completely aroused. *Nightmare*, *ephialtes* or *incubus* affords us an example of suffering as intense as could well be experienced during our waking moments. A sensation of distressing weight is felt at the epigastrium, and of impossibility of motion, speech, or even respiration; the dreamer fancies that some horrible form, or ferocious being is approaching him, and that all chance of escape is precluded; or that he is about to fall, or is falling, from a lofty precipice; and the anguish he suffers is indicated by loud groans, or by such painful feelings, apparently in the organs to which the emotions are referred, that he awakes. The ideas, at these times, are even more vivid than during the waking condition; the predominant perceptions not being detracted from by extraneous impressions. On many of these occasions, when we awake, the dream is fresh on the memory; and by resigning ourselves again to slumber, we can at times, recall it, should it be of an agreeable character,—or dispel it altogether by rousing ourselves thoroughly.

On account of the greater vividness of the ideas during sleep, and their freedom from all distraction, intellectual operations are sometimes effected in a surprising manner;—difficulties being occasionally solved, which have obtained the mastery during waking. To a minor degree, every one must have experienced more or less of this. Composition, poetical or other, is often effected with great facility; and a clue is occasionally afforded, which leads to the solution of previous difficulties. Cardan had a notion, that he composed one of his works during sleep. Condillac, who attended greatly to this matter, remarked particularly, that, whilst engaged with his "*Cours d'Etude*," he frequently broke off a subject before retiring to rest, which he developed and finished the next morning according to his dreams. Condorcet saw in his dreams the final steps of a difficult calculation, which had puzzled him during the day; and Dr. Gregory, of Edinburgh, composed thoughts, and clothed them in words, which were so just in point of reasoning, and so good in point of language, that he used them in his lectures, and in his written lucubrations. Voltaire, Lafontaine, Franklin, Coleridge, and others, have made similar remarks; and events of the kind must have occurred, in some shape, to almost every one. Dr. Good relates a singular instance that happened to a friend of his, who, amongst other branches of science, had deeply cultivated music, of which he was passionately fond. He was a man of irritable temperament, ardent mind, and active and brilliant imagination; and "was hence," says Dr. Good, "prepared by nature for energetic and vivid ideas in his dreams." On one occasion, during sleep, he composed a beautiful little ode, of about six stanzas, and set the same to agreeable music, the impression of which was so firmly fixed in his memory, that, on rising in the morning, he copied from his recollection both the music and the poetry.

In these cases, the will must direct, more or less, the intellectual process. It is scarcely conceivable, that the train of reasoning could go on so connectedly and effectively by association alone. That the will can, in some degree, be kept awake, or in a condition susceptible of being readily aroused, is shown by the facility with which we awake

at a determined hour, and exercise a degree of watchfulness during sleep; as well as by the facts, previously mentioned, regarding the courier who sleeps on his horse, or the coachman on his box.

One curious fact, occasionally observed in dreams and likewise in the Mesmeric condition, which is analogous, in many respects, to what occurs in dreaming, is the calling up of impressions, that have been made at an antecedent period, and may have been entirely forgotten during the waking state. A well-known case of this kind is recorded in the books. A woman, during the delirium of fever, constantly repeated sentences unknown to her attendants, which proved to be Hebrew and Chaldaic. Of these she knew nothing whatever on her recovery; but on referring to her previous condition, it appeared, that she had formerly lived with a clergyman, who had been in the habit of reading aloud sentences in those languages; and these had impressed her mind without her knowledge.

Dr. Dewar relates the case of a girl, who, when awake, discovered no knowledge of astronomy, or other sciences; but when asleep could define the rotations of the seasons, using expressions the most apt to the subject; and Mr. Dendy[1] alludes to the case of an Edinburgh lady, who, "during her somnolent attacks, recited somewhat lengthy poems;" and it was curious, that each line commenced with the final letter of the preceding.

There is a kind of dreaming, in which the sleep is less profound than during ordinary dreams; and in which the body has, consequently, more capability of receiving external impressions, but the will has a certain degree of power over the muscles of voluntary motion, and imperfectly regulates the thoughts. This is *somnambulism* or *sleep-walking.* During the continuance of this state, the individual can apparently see, hear, walk, write, paint, speak, taste, smell, &c., and perform his usual avocations, yet remain, in other respects, so soundly asleep, that it is impossible to awake him without making use of violence. Cases are on record, and of an authentic nature, of individuals who have risen from bed asleep, with their eyes closed, and have not only walked about the room or house, going up or down stairs, finding their way readily and avoiding obstacles, but have passed with safety through very dangerous places, as windows, to reach the roofs of houses. They have executed, too, yet more difficult feats; such as dressing themselves; going out of doors; lighting a fire; bathing; saddling and bridling a horse; riding; composing verses, &c., and executing all the acts of life correctly, and even acutely; yet they were asleep during the whole time. The eyes have been shut, or, if open, have been incapable of perceiving the brightest light held before them; and the iris has not exhibited its irritability by contracting; so that it has been doubtful whether the ordinary functions of the eyes are generally executed during somnambulism; and the fact of the serious accidents, that occasionally befall the sleep-walker, is in favour of the negative. It must be remarked, however, that, in the opinion of some physiologists,

[1] The Philosophy of Mystery, p. 305, London, 1841.

the sight is awake and employed; and there are cases which strongly favour the idea. In these cases, the movements are regulated and co-ordinated; and if the cerebellum presides over this function—as is generally believed—it must be awake.

A peculiarity of ordinary somnambulism is, that the train of thoughts is usually directed towards one point, and this so profoundly, that notwithstanding the activity of the imagination, and the firm hold it takes on the mind, no recollection is retained of the occurrences during sleep, after the individual awakes either spontaneously or on being aroused.

Animal magnetism would seem to be capable of inducing a peculiar kind of somnambulism or *hypnotism*—as Mr. Braid[1] has termed it—in which new powers appear to be acquired, and intellectual operations executed of a most astonishing character. The records of the *Académie Royale de Médecine*, of Paris, contain many such instances. A singular case of somnambulism is recorded by Dr. Belden, of Springfield, Vermont.[2] It occurred in a young female, 17 years of age; and the phenomena were attested by numerous observers. One striking circumstance in the case was the astonishingly developed impressibility of the eye. As an evidence of this, when Dr. Belden, in order to test the sensibility of the organ, took, one evening, a small concave mirror, and held it so that the rays proceeding from a lamp were reflected upon her closed eyelid: when the light was so diffused, that the outline of the illuminated space could scarcely be distinguished the moment it fell on the eyelid, it caused a shock equal to that produced by an electric battery. This female could see as well, apparently, when the eyes were closed as when they were open. The details of the case—and indeed of every case—of somnambulism are full of interest to the mental philosopher.

Of late, the various experiments, at one time so much in vogue, when Mesmerism was in fashion,—have been repeated not only by those who are not in the ranks of the profession, but by some estimable physicians; and of the reality of certain of the effects ascribed to the manipulations of the animal magnetizer no doubt can be entertained. The whole history of the art exhibits, that impressible individuals may have irregularities of nervous distribution induced through the medium of the senses, especially through those of vision and touch,—and that somnambulism and hysteric sleep, with other phenomena referable to a like condition of the nervous system, may be engendered; but that there is any thing like a magnetic fluid or agent, which may be communicated from the magnetizer to the subject of his experiments, is not only not proved, but in the author's opinion, by no means presumable. Mr. Braid,[3] indeed, affirms, that the most effectual of all modes of inducing somnambulism is for the subject himself to take any bright object—Mr. Braid generally uses his lancet case—between the thumb and fore and middle fingers of the left hand; hold it from about eight

[1] Neurypnology, or the Rationale of Nervous Sleep, considered in Relation with Nervous Magnetism; and Edinburgh Medical and Surgical Journal, Oct, 1846; copied into Amer. Journal of the Medical Sciences, Jan., 1847, p. 231.

[2] American Journal of the Medical Sciences, No. xxviii.

[3] Op. cit., and Carpenter, art. Sleep, Cyclop. of Anat. and Physiology, Pt. xxxv. p. 695, March, 1849.

to fifteen inches from the eyes, at such a position above the forehead as may be necessary to produce the greatest possible strain upon the eyes and eyelids; and enable the subject to maintain a steady fixed stare at the object. After a time, in a proper individual, the phenomena will present themselves. Some years ago, the author knew a highly *hypnotizable* gentleman, who could speedily induce the phenomena on himself by looking at a pointed metallic body—the point of his penknife for example.

A most curious phenomenon presented by this singular condition is the greatly developed sensibility to some irritants, and the total insensibility to others. Thus, the author has seen different persons bear without the slightest muscular contraction the application of a straw or feather to the conjunctiva; the insertion of pointed bodies into various parts of the cutaneous surface; the extraction of a tooth, &c., and yet start at the least puff of air on the face. From what the author has himself seen, he can readily credit the statements affirmed on respectable testimony, that even the major operations of surgery may have been executed whilst the patient was in this state of *Mesmeric sleep*—if it may be so termed. As to the Hellsehen, *clairvoyance*, or "lucidity of vision," said to have been possessed by the magnetized, could he assign his belief to it at all, it would be only on the ground—"*credo quia impossibile est.*"

One of the most startling of recent announcements was, that if a compartment of the skull, mapped out by the phrenologists, be touched, whilst a person is in the Mesmeric state, he will immediately have his thoughts turned in the direction of the mental faculty that corresponds with the particular phrenological organ, and exhibit manifestations thereof in his actions and speech. Some of the phenomena witnessed by the author have certainly been most strange; and at first sight were strongly confirmatory of a union between phrenology and magnetism or "*phreno-magnetism*," and, therefore, of the truth of both. It has been sufficiently demonstrated, however, that where the person operated upon has had no previous acquaintance of any kind with phrenology, not the slightest manifestation can be elicited; and that by stating aloud, that the manipulator is about to touch a certain organ, whilst, in reality, he touches another, the thoughts and actions have been immediately made to correspond with the organ mentioned—not with the one over which the finger was placed.

The causes of imperfect or incomplete sleep, and hence of dreams, are various. The fact, already referred to, of the different organs of the animal functions having their distinct periods of waking and rest, would induce us to suppose, that it ought not to be always equally profound and durable: yet there are persons whose sleep is nearly complete throughout. The previous occupation of the sleeper exerts great influence. If it has been of a fatiguing nature, all the faculties rest equally long and soundly; but if the fatigue extends beyond the due point, a degree of excitability of the brain is left which renders it extremely liable to be aroused. In this way we understand why dreams should bear upon subjects that have long occupied the mind in its waking state—the tension of the mind on those subjects having left greater

excitability, as respects them, and a disposition to resume them under the slightest irritation. The presence or absence of irritants—external or internal—exerts likewise a great effect on the soundness of sleep, and the formation of dreams. The stillness of night and absence of light are hence favourable to repose; the position, too, must be one devoid of constraint; and the couch soft and equable, and especially such as the individual has been accustomed to. Sleep is impracticable in a badly made bed; and every one must have experienced the antisoporific influence of a strange couch, the arrangement of which, as to size, pillows, &c., differs from that to which he has been habituated. It is not, however, by external irritants that sleep is usually disturbed. The state of the system itself may react upon the brain and give occasion to broken sleep, and to dreams of a most turbulent character. Irritations existing in the viscera are frequently the cause of dreams,—in children more especially; and a hearty supper, particularly if of materials difficult of digestion, may bring on the whole train of symptoms that characterize nightmare. In like manner, any thing that impedes the action of the functions of respiration, circulation, &c., may occasion the wildest phantasies. All these internal impressions are more vividly perceived for the reasons already stated. The nervous system is no longer excited by the ordinary impressions from the external senses; and if the internal impressions be insufficient to prevent sleep altogether, they may excite dreams.

During this incomplete kind of sleep, the external sensations are not wholly at rest; particularly that of touch or tact, which, as it is the last to sleep, is the first to awake. Impressions made on it may excite the most exaggerated representations in the brain, in the shape of dreams. The bite of a flea appeared to Des Cartes the puncture of a sword: an uneasy position of the neck may excite the idea of strangulation: a loaded stomach may cause the sleeper to feel as if a heavy weight,—a house or castle, or some powerful monster,—were on his stomach. A person, having had a blister applied to his head, dreamed that he was scalped by a party of Indians. Moreau de la Sarthe gives the case of a young female, who, from the application of her cold hand against her breast, when asleep, dreamed that a robber had entered her apartment, and had seized hold of her. Galen dreamed that he had a stone leg, and, on waking, found that his own was struck with paralysis. Mr. Dugald Stewart[1] gives a similar case, to show how an impression made upon the body, during sleep, may call up a train of associated ideas, and thus produce a dream. A gentleman, (Dr. Gregory,) who, during his travels, had ascended a volcano, having occasion, in consequence of indisposition, to apply a bottle of hot water to his feet when he went to bed, dreamed that he was making a journey to the top of Mount Ætna, and that he found the heat of the ground almost insupportable. Sir Walter Scott[2] mentions an analogous instance, which was told him by the nobleman concerned. He had fallen asleep, with some uneasy feelings arising from indigestion, which

[1] Elements of the Philosophy of the Human Mind, i. 335, 3d edit., Lond., 1808.
[2] Letters on Demonology and Witchcraft, Amer. edit., p. 49, New York, 1830.

brought on the usual train of visionary terrors. At length, they were all summed up in the apprehension, that the phantom of a dead man held the sleeper by the wrist, and endeavoured to drag him out of bed. He awoke in horror, and still felt the cold dead grasp of a corpse's hand on his wrist. It was a minute before he discovered, that his own left hand was in a state of numbness, and that he had accidentally encircled his right arm with it. On another occasion, Dr. Gregory dreamed of spending a winter at Hudson's Bay, and of suffering much distress from the intense frost—the dream being evidently the consequence of his having thrown off the bedclothes in his sleep, added to his having been reading, a few days before, a very particular account of the state of the colonies in that country during winter. Dr. Reid, having a badly dressed blister on his head, dreamed that Indians were scalping him; and a man in a damp bed dreamed that he was being dragged through a stream.[1] If, again, the organ of hearing be wakeful, the dreamer may hear a person speak to him, and reply; so that occasionally secret thoughts and feelings may be elicited. The author has himself answered several times connectedly in this manner; and has been able to lead others, especially children,—whose sleep is often interrupted by the existence of irregular internal impressions,—to respond a few times in the same way.

It would seem, that on the loss of any one sense, the dreams, after a lapse of time, cease to refer to it. Dr. Darwin has given many instances of this. After blindness had long affected certain persons, they never dreamed that they saw objects in their sleep; and a deaf gentleman, who had talked with his fingers for thirty years, invariably dreamed of finger-speaking; and never alluded to his having dreamed of friends having conversed orally with him.

In the explanation of the cause of dreaming, we have the most plausible application of the theory of Gall regarding the plurality of cerebral organs. Every explanation, indeed, takes for granted, that certain faculties are suspended whilst others are active. Gall's view[2] is, that, during sleep, particular organs of animal life enter into activity; and hence, that the perceptions and ideas, which depend on these organs, awake; but, in such case, their activity takes place without any influence of the will;—that when one organ only is in activity, the dream is simple: the dreamer caresses the object of his affection; he hears melodious music, or fights his enemies, according as this or that organ is exercising its functions;—that the greater the number of organs in activity at the same time, the more confused or complicated will be the dream, and the greater the number of extravagancies;—that, when the organs are exhausted by watching and labour, we generally do not dream during the first hours of sleep, unless the brain is extremely irritable; but, in proportion as the organs get rid of their fatigue, they are more disposed to enter into activity, and hence, near the time for waking, we dream more, and with greater vivacity. "Dreaming, consequently," he concludes, "is only a state of partial

[1] Carpenter, Art. Sleep, op. cit., p. 688.
[2] Sur les Fonctions du Cerveau, ii. 506, Paris, 1825.

waking of animal life; or, in other words, an involuntary activity of certain organs, whilst others are resting."

In many respects, the state of the mind during dreaming resembles that in the delirium of fever, as well as in insanity. The imagination and memory may be acting with unusual vivacity, whilst the perception or the judgment may be erroneous;—at times, the perception being accurate and the judgment suspended, so that the individual may be most incoherent; at others, the perception being inaccurate and the judgment right, so that he may reason correctly from false premises. As in dreams, too, the delirious may have their ravings modified by impressions made on the external senses. Sir Walter Scott[1] cites the case of a lunatic confined in the Infirmary of Edinburgh, whose malady had assumed a gay turn. The house, in his idea, was his own, and he contrived to account for all that seemed inconsistent with his imaginary right of property. There were many patients in it, but that was owing to the benevolence of his nature, which made him love to relieve distress. He went little, or rather never, abroad,—but then his habits were of a domestic and rather sedentary nature. He did not see much company, but he daily received visits from the first characters in the celebrated medical school of the city; and he could not, therefore, be much in want of society. With so many supposed comforts around him, with so many visions of wealth and splendour, one thing alone disturbed his peace. "He was curious," he said, "in his table; choice in his selection of cooks; had every day a dinner of three regular courses and a dessert, and yet somehow or other, everything he ate tasted of porridge." The cause of this was, that the lunatic actually ate nothing but porridge at any of his meals; and the impression made upon his palate was so strong as to modify his delusion.

2. WAKING DREAMS.

Nearly allied to dreams, in its physiology, or—more properly, perhaps—pathology, is the subject of *hallucinations, spectral illusions* or *waking dreams*, in which the mind may be completely sound, and yet the part of the brain concerned in perception be so deranged as to call up a series of perceptions of objects, that have no existence except in the imagination. Such hallucinations are constant concomitants of insanity, delirium, and dreaming; but they may occur, also, when the person is wide awake, and in the full possession of his reasoning powers: he may see the phantasm, but at the same time totally disbelieve in its existence. The most common illusions of this kind affect the senses of sight and hearing.

It has fallen to the lot of the author to meet with singular and serious cases of this affection; where, for example, the person wide awake, has heard the doors of his house violently slammed; his windows thrown up and down; the bells set a ringing; himself subjected to personal violence; yet there has been no slamming of doors, no throwing up and down of windows; no ringing of bells; no personal violence: the whole has been an illusion, a waking dream, and of this

[1] Op. citat., p. 26.

no one has been more entirely aware than the sufferer himself. A few years ago, the author was consulted by a most respectable citizen of Virginia, regarding his state of health as well as an illusion of this nature. He was one of the Board of Visiters at West Point, where his duty required him to inspect the demonstrations of the pupils on the black-board. For months after his return to Virginia, he saw the black-board with its demonstrations constantly before him. He had previously experienced an attack of paralysis, and, when he applied to the author, was labouring under marked evidences of predisposition to a farther access of encephalic mischief, of which the illusion in question was doubtless one. A most impressive case of the kind is that of Nicolai, the eminent bookseller of Berlin, which has been detailed by Drs. Ferriar[1] and Hibbert,[2] and by Dr. Haslam[3] and Mr. Mayo.[4] Nicolai laid his case before the Philosophical Society of Berlin. He traced his indisposition,—for it was manifestly such,—to a series of disagreeable incidents that had befallen him. The depression, thus induced, was aided by the consequences of neglecting a course of periodical bleeding to which he had been accustomed. This state of health brought on a disposition to spectral illusions; and, for a time, he was regularly haunted by crowds of persons entering his apartment, and addressing him or occupied solely in their own pursuits; until, as his health was restored, they gradually disappeared, and ultimately left him entirely. Yet Nicolai, who was a man of unusually strong intellect, was satisfied throughout, that they were mere hallucinations.

The cases of the kind, now on record, are many and curious. Every one engaged in extensive practice, or in frequent communion with the world, must have seen or heard of them. Some, of a deeply interesting character, are detailed by Sir David Brewster,[5] Dr. Abercrombie,[6] and Dr. Macnish;[7] but there are none more extraordinary than those that have been related by Sir Walter Scott.[8] They are signal examples of the illusions that may occur during even our waking moments; and may, doubtless, account for some of the stories of apparitions, of which so many are on record. In the hypochondriac, we meet with all kinds of hallucination, and it is one of the most striking of the symptoms of every variety of insanity; but, in the cases referred to, notwithstanding the constancy and permanency of the illusion, the individual himself has been satisfied, that the whole affair had no real existence. Had he believed in the existence of the phantom, and acted from a conviction of its reality, he might, with propriety, have been deemed insane *quoad hoc*. An instance of this kind is told in the Memoirs of the Count Maurepas of one of the princes of the House of Bourbon, who supposed himself a plant; and having fixed

[1] An Essay towards a Theory of Apparitions, Lond., 1818.
[2] Sketches of the Philosophy of Apparitions, Edinb., 1825.
[3] Medical Jurisprudence as it relates to Insanity, in Cooper's Tracts on Medical Jurisprudence, p. 302, Philad., 1819.
[4] Outlines of Human Physiology, 3d edit., p. 213, Lond., 1833.
[5] Letters on Natural Magic, Amer. edit., p. 42, New York, 1832.
[6] Inquiries concerning the Intellectual Powers and the Investigation of Truth, Amer. edit., p. 282, New York, 1832.
[7] Philosophy of Sleep, Amer. edit., p. 214, New York, 1834.
[8] Letters on Demonology, &c., Amer. edit., p. 34, New York, 1830.

himself in the garden, called upon his servant to come and water him. His belief argued unsoundness of mind; yet the hallucination, we are told, appeared to be confined to this subject. Usually, these spectral illusions persist, until the morbid cause producing them is removed. All, indeed, that have fallen under the author's notice, have been of this character. No matter where the individual may be, the phantom is present. It is affirmed, however, in a recent medical periodical,[1] that a gentleman of Boston, known for his intelligence and enterprise, has had for years past a hallucination, whenever he enters a certain gate in front of a relative's house. He is met by a large, full-faced, florid-complexioned man, dressed in a broad-brimmed white hat. This occurs at all hours of the day. The spectre recedes from him as he advances; and, near the house, is lost in air. The gentleman assured the editor of the journal, that he takes pleasure in looking his intangible visiter full in the eye; examines the colour and fashion of his garments; and now regards him as an old and familiar acquaintance. In this case, the hallucination is evidently called up by morbid associations connected with the particular impression made on the brain by local objects through the sense of sight; and does not exist except when such objects are present. In youth, when imagination is extremely vivid, we can call up images in the mind at pleasure, varying them as we may think proper. In the nervous, the delicate, and the imaginative, uneasy sensations may be felt when and where the individual wishes. After long continued sedentary habits, the author has been able to experience, at will, pain in any part of the system, and to make it shift at pleasure from one organ to another.

In the cases of hallucination, referred to above, as well as in every other kind, the cerebral part of the organ of sense is directly or indirectly excited into action;—often by disease of the brain, or of some distant organ which reacts upon it. Hence it occurs as a precursor of apoplexy, epilepsy or other cerebral affection; or it may accompany, or be aggravated by, disorder of the digestive function. It has been seen, that although the passions or emotions are cerebral phenomena, they are felt in the nutritive organs; and we can understand how a disordered state of those organs may react upon the brain, and call up all kinds of illusions;—generally during sleep, but at times even during our waking moments. In this way, we account for the frightful dreams that follow an overloaded stomach, or accompany impeded respiration or circulation. One of the most distressing symptoms of hydrothorax or water in the chest, a disease that interferes more or less with both these vital functions, is the disturbed sleep, and frightful sense of impending danger, which nightly distress the unfortunate sufferer.

It appears, then, that in all cases of hallucination, occurring in those of sound or diseased mind, asleep or awake, the encephalic or percipient part of the organ of the sense concerned is irresistibly affected, so as to call up the memory of objects, or to form others that have no existence except in the imagination; but all this is accomplished without any impression being made upon the external senses from without, even when these senses appear to be most actively exercised. In dreams,

[1] Boston Medical and Surgical Journal, 1846.

this must manifestly be the case. We see a friend long since dead; we parade the streets of a town we have never visited; and see, hear, feel, and touch the different objects. All this must be encephalic; and not less certainly is it the case in the hallucinations of insanity, or in those that occur in the waking condition. The object we see is not in existence, yet it is a regularly defined creation; a cat in one instance, a gentleman-usher in another, and a skeleton in a third. It cannot depend upon any depraved condition of the organ of sense, as in such case the representation of the mind would be amorphous, irregular, or confused; not a complete metamorphosis, as is invariably the case. Yet Sir Walter Scott[1] states, that he thinks "there can be little doubt of the proposition, that the external organs may, from various causes, become so much deranged as to make false representations to the mind; and that, in such cases, men, in the literal sense, really *see* the empty and false form, and *hear* the ideal sounds, which, in a more primitive state of society, are naturally enough referred to the action of demons or disembodied spirits. In such unhappy cases, the patient is intellectually in the condition of a general, whose spies have been bribed by the enemy, and who must engage himself in the difficult and delicate task of examining and correcting, by his own powers of argument, the probability of the reports, which are too inconsistent to be trusted to." The explanation is poetic, but manifestly untenable.

A theory, which has been offered to account for the various spectral illusions occurring in any of the modes mentioned, is—that in all the organs of sense, the mind possesses the power of retransmitting, through the nervous filaments, to the expansions of the nerves that are acted upon by external objects, impressions, which these nerves have previously transmitted to the brain, and, that the vividness of the retransmission is proportional to the frequency with which the impressions have been previously transmitted; that these reproduced impressions are in general feeble in the healthy state of the body, though perfectly adapted to the purposes for which they are required; but, in other states of the body, they appear with such brilliancy as to create even a belief in the external existence of those objects from which the impressions were originally derived. "When the mind," says a writer on this subject, "acquires a knowledge of visible objects it is by means of luminous impressions conveyed to the sensorium from each impressed point of the retina through the corresponding filaments of the optic nerve; and when the memory is subsequently called upon, by an act of the will, to present to us an object that has been previously seen, it does it by retransmission along the same nervous filaments, to the same points of the retina. In the first case, when the presence of the luminous object keeps up a sustained impression upon the nervous membrane, the filaments, which transmit it to the brain, are powerfully excited; but, in the process of retransmission by an effort of memory, the action of the nervous filaments is comparatively feeble, and the resultant impression on the retina faint or transient. When the memory, however, is powerful, and when the nervous filaments are in a state of high excitability, the impression becomes more vivid; and, as in the case of spectral illu-

[1] Op. cit., p. 40.

sions, it has the same strength and distinctness, as if it were produced by the direct action of luminous rays. In one case, the result of the impression and its retransmission to the retina is a voluntary act of the mind, but, in the other, it is involuntary, the controlling power being modified or removed, or the nerves being thrown into a state of easy excitation by some unhealthy action of the bodily organs."

According to this view, it is indispensable, that perception, in every case of illusion, shall be referred to the nerves of the organ by which such perception is ordinarily effected; to the retina, if vision; to the auditory nerve, if audition be concerned; and so on. But this retransmission along the nerves would appear to be wholly unnecessary. When an impression is made upon a sensitive surface, as we have elsewhere shown, sensation is not accomplished until the impression has been conveyed to the brain, and the brain has acted; and if we interfere in any manner with the cerebral part of the function, perception is not effected. From the moment, however, that the action of the brain has taken place, the idea formed can be recalled by the exercise of memory; and we have no doubt that this could take place for a time, although the eyes were extirpated. The memory may call up previous perceptions, when the functions of the retina are entirely destroyed. In dreams we exert every one of the senses; some with the greatest activity. We see, hear, taste, smell, and feel; and, in addition to this, seem to walk, run, fly, and execute the ordinary acts of life not only without apparent difficulty, but with a facility that surprises us. Yet can we suppose, that in all these cases, feeling is actually produced by retransmission along the nerves of the organ to which it is referred? It has been asserted, that when examination is carefully made it will be found, that the images recalled by the memory, follow the motions of the head and eye; but, that this is not the case during sleep is manifest. The individual may remain in the same position, and yet seem to move about in all directions in his dreams; appear to see objects behind as well as before him; and in situations towards which it is impossible that the motions of his head and eye should be directed. Even in most of the illusions of our waking hours, the remark ought to be reversed. The encephalic action is the first of the links in the chain of phenomena; and the motions of the head and eye follow the images recalled by the memory. When the unfortunate subject of one of the cases of hallucination recorded by Sir Walter Scott saw the gentleman-usher preceding him into company, and circulating among the assembled guests —as well as when he observed the skeleton at the foot of his bed—the perception, owing to disease, had so completely taken possession of a part of the encephalic organ of vision, that the idea was constantly in the mind; and volition being actively exercised, the head and eye were directed towards the phantasm. Yet the perception was not so powerful as to preclude the reception of impressions from without, as was shown by the skeleton seeming to be shut off by the body of the physician, so that the skull only was seen peering above his shoulder.

Another fact, which shows, that the whole phenomenon may be entirely encephalic, is the occurrence, familiar to the operative sur-

geon, of a patient, whose lower limb has been amputated, complaining of an uneasy sensation, as of itching, in a particular toe, and in a particular part of a toe. This is, at times, a symptom of an extremely distressing character. It is obviously impossible, that in such a case there can be any external impression made on the part to which the feeling is referred; or that any retransmission can occur from the brain—the limb having been removed from the body. M. Broussais asserts, that if a person tells you he suffers in a limb which he no longer has, it is because he experiences irritation in the extremities of the divided nerve; but this, in no respect, removes the difficulty. The sensation is referred to a part, which has no existence except in the imagination.

But, to return to sleep. We have said, that the object of sleep is to repair the loss sustained by the nervous system, during the previous condition of waking. This may, consequently, be regarded as the great exciting cause of sleep; but we have seen, also, that certain states of the mind may postpone the usual period of its recurrence. If, indeed, we allow the attention to flag, and suspend the due exercise of volition, sleep can be indulged at almost any hour of the day. In the same manner, any monotonous impression, or action of the brain in thought; the rocking of a cradle, or the song of the nurse to a restless child; the murmurs of a bubbling brook, &c., may soothe to rest. A like effect is produced by substances, as narcotics, which, by a specific action on the nervous system, prevent the ordinary sources of irritation from being appreciated, as well as by certain morbid affections of the brain—compression, concussion, inflammation, &c. In these cases, however, the sleep is morbid, and an evidence of serious mischief—often of fatal disease; whilst true sleep is as natural as the waking state, and is always—

> "Man's rich restorative; his balmy bath,
> That supples, lubricates, and keeps in play
> The various movements of that nice machine,
> Which asks such frequent periods of repair."
>
> YOUNG'S *Night Thoughts.*

Yet Haller,[1] Hartley,[2] and numerous others have supposed, that natural sleep is dependent upon an accumulation of blood or other fluids in the vessels of the head pressing upon the brain, and thus impeding its functions. In support of this opinion, it is asserted, that all the phenomena which attend the sleeping state seem to prove a determination of blood to the head. The face is flushed; the head hotter; the skin more moist; and it is generally during the night, or when first awake, that bleeding from the nose and apoplexy take place; the frequency of erection during sleeping is affirmed to be owing to the pressure exerted on the cerebellum, which, in the theory of Gall, is the encephalic organ of generation; and, lastly, it is argued, that narcotics, and vinous and spirituous liquors produce sleep by causing a similar congestion of blood within the cranium. The case, by no means unique, of the beggar whose brain was exposed, and in whom a state of drowsi-

[1] Element. Physiolog., xvii. 3. [2] On Man, p. 45, Lond., 1791.

ness was induced when it was pressed upon, which could be increased by increasing the pressure, until at length he became comatose,—has also been cited by Hartley and others. But most of these are cases of morbid suspension of the animal functions, and are no more to be likened to true sleep, than the drowsiness, which M. Flourens[1] found to prevail in his experiments on animals when the cerebral lobes were removed.

The believers in the hypothesis, that congestion of the vessels of the brain is the cause of sleep, consider that the heaviness and stupor, observable in those who indulge too much in laziness and sleep, are owing to long-continued pressure injuring the cerebral organs. Other physiologists have assumed the opposite ground, and affirmed, that during sleep the blood is distributed to the brain in less quantity, and is concentrated in the abdomen, to augment the action of the nutritive functions; whilst M. Cabanis[2] holds, that during sleep there is a reflux of the nervous powers towards their source, and a concentration in the brain of the most active principles of sensibility. On all these topics our ignorance is extreme. We know nothing of the state of the encephalon in sleep. Its essence is as impenetrable as that of every other vital function. Dr. Bostock[3] asserts, that it is not more beyond our grasp than other functions of the nervous system. This we admit; he has, indeed, afforded in his own work indubitable evidences of our utter want of acquaintance with the essence of all those functions.

The state of sleep is as natural, as instinctive, as that of waking; both are involved in mystery; and their investigation, as Mr. Dugald Stewart[4] has suggested, is probably beyond the reach of the human faculties.

3. REVERY.

Revery has been considered to resemble sleep, and, in its higher grades, to be not far removed from the condition of somnambulism. It is characterized by the attention or volition being directed so intently towards particular topics, during wakefulness, that the impressions of surrounding objects are not appreciated. Various grades of this condition of the mind may be traced, from the slightest degree of *absence* or *brown study* to a state in which the attention is entirely wound up, and riveted on a particular subject. Most persons must have experienced more or less of this, when any subject of severe study, or any great gratification, anxiety, or distress has strongly occupied the mind. If engaged in reading, they may follow every line with the eye; turn over leaf after leaf; and at length awake from the revery, which had occupied the imagination, and find that not the slightest impression had been made on the mind by the pages, which the eye had perused, and the hand had passed over. If walking in a crowded street, they may have proceeded some way under the influence of revery, moving the limbs as usual, performing various acts of volition, winding safely among the passengers, avoiding the posts and other obstacles, yet so exclusively

[1] Expériences sur le Système Nerveux, Paris, 1825.
[2] Rapport du Physique et du Moral de l'Homme, Paris, 1802.
[3] Elementary System of Physiology, 3d edit., p. 815, Lond., 1836.
[4] Elements of the Philosophy of the Human Mind, i. 327, 3d edit., Lond., 1808.

occupied by the conceptions of the mind, as to be totally unconscious of all these acts of their volition, and of the objects they have passed, which must necessarily have impressed their senses so as to regulate those actions; but, owing to the attention having been bent upon other topics, the perceptions were evanescent. In elucidation of the power of a high degree of revery to render an individual torpid to all around him, the case of Archimedes, at the time of his arrest, has been quoted by writers. When the Roman army had at length taken Syracuse by stratagem, which the tactics of Archimedes had prevented them from taking by force, he was shut up in his closet, and so intent on a geometrical demonstration, that he was equally insensible to the shouts of the victors, and the outcries of the vanquished. He was calmly tracing the lines of a diagram, when a soldier abruptly entered his room, and clapped a sword to his throat. "Hold, friend," says Archimedes, "one moment, and my demonstration will be finished." The soldier, surprised at his unconcern at a time of such extreme peril, resolved to carry him before Marcellus; but as the philosopher put under his arm a small box-full of spheres, dials, and other instruments, the soldier, conceiving the box to be filled with gold, could not resist the temptation, and killed him on the spot.[1]

It is to the capability of indulging to the necessary extent in this kind of mental abstraction, that we are indebted for the solution of every abstruse problem, relating to science or art, and for some of the most beautiful conceptions of the poet. From indulgence, however, in such abstractions, a habit is often acquired, which may be carried so far as to render the individual unfit for society, and give him a character for rudeness and ill-breeding, of which he may be by no means deserving. Some most amiable and estimable men have, from long habits of abstraction, contracted the *disease* (*aphelxia*), as Dr. Good[2] has constituted it, and have found the cure tedious and almost impracticable; at times, indeed, it appears to have terminated in mental alienation. The difference between this state and that of sleep is, that the attention and volition are here powerfully directed to one object, so as to be torpid to the impressions of extraneous bodies; whilst sleep is characterized by a suspension or irregular exercise of these faculties.

CHAPTER III.

CORRELATION OF FUNCTIONS.

The wonderful and complicated actions of the frame are variously correlated to accomplish that astonishing harmony, which prevails in the state of health, as well as to produce the varied morbid phenomena,—often at a distance from the part originally diseased,—which characterize different pathological conditions. It is not, therefore, simply as a physiological question, that the study of the correlation of

[1] Liv. l. xxxv., c. 3.
[2] A Physiological System of Nosology, cl. iv., ord. 1, gen. v.

functions interests the medical inquirer. It is important to him in the study of every department, which concerns the doctrine of the healthy or diseased manifestations, and the modes adapted for the removal of the latter. The correlations may be of various kinds;—*mechanical*, in which the effect exerted is entirely of a mechanical character; *functional*, in which the action of one organ is inseparably united to that of another, to accomplish a particular object; and *sympathetic*, in which there is no physical action or direct catenation of functions, but where an organ at a distance from one affected is excited to regular or irregular action in consequence of the condition of the latter.

1. MECHANICAL CORRELATIONS.

In the description of the different functions, numerous opportunities occurred for showing the influence which organs, in the immediate vicinity of each other, may mutually exert so as to modify their functions. The action of the muscles,—particularly those that contract the larger cavities, as the abdomen and thorax,—on the parts with which they come in contact, must be entirely mechanical. In this way, the diaphragm and abdominal muscles act in vomiting and defecation. During the operation of blood-letting, the flow of blood can be augmented by moving the muscles of the hand; and it is probable, that the constant motion of the muscles of respiration impresses a succussion on different organs, which may aid them in accomplishing their functions, although the effect of this is doubtless exaggerated. Every change of position, either of the whole body or of a part, has likewise some effect in modifying the actions performed by it or by neighbouring organs, although such effect may not be easily appreciable. A similar case of mere mechanical influence, which seems to be important to the proper action of certain organs, is exhibited in the pulsation of the different arteries. It has been seen, that a succussion is in this way given to the brain, which appears to be necessary to it; for if this source of stimulation be in any manner withdrawn fainting is induced. Perhaps, however, the strongest case that can be offered of modification of function by mechanical causes, is that of the gravid uterus, which, by its pressure, gives rise to numerous symptoms in other organs, that are often the source of annoyance during gestation.

2. FUNCTIONAL CORRELATIONS.

The *functional correlations* or *synergies* are of much more moment to the physiologist and pathologist. Many of these have also been described in the preceding history: a brief notice of them will be all that is now requisite. For the maintenance of the healthy function we know that certain conditions are necessary, and that if these be materially modified, in the whole or in any part of the body, disease and death may be the result, even although the derangement may, in the first instance, concern only an apparently unimportant part of the frame,—the affection, by correlation, spreading gradually to more and more essential organs and functions, until the disorder is ultimately too great to allow of a continuance of the vital movements. In this respect, man differs from an ordinary piece of mechanism, in which

the various parts are so adapted to each other as to produce a certain result. If one of these parts be destroyed, the whole machine may have its motion arrested; but the effect is owing to the destruction of one part only, the others remaining sound; whilst death, or the stoppage of the living machine, does not necessarily follow the destruction of any except a few essential organs, and is generally owing to the derangement of many. We shall find, indeed, that except in cases of sudden death, it is extremely difficult to say which of the three truly vital organs has first ceased to act; and that in all such cases death begins in one or other of the organs essential to vitality, and soon extends to the rest.

The essentially vital organs are those of respiration, circulation, and innervation; but the great use of respiration is to change the blood from venous to arterial; in other words, to induce a conversion in it by its passage through the lungs, without which it would be inadequate for the maintenance of life in any organ; and the object of the circulation is, to distribute it to the various parts of the frame as the grand vivifying and reparatory material. If, also, the organs of innervation be destroyed, the nervous influence is no longer conveyed to the different parts of the frame; and as the presence of this influence is indispensable, the functions may cease from this cause; so that we may regard as essential elements to the existence of the frame and of every part of it a proper supply of arterial blood and nervous influence. In the production and distribution, however, of these agencies, a number of functions is concerned, giving rise to the correlation, which is the object of the present inquiry. If, in any manner, the blood do not meet with due aeration, as in ordinary cases of suffocation, death supervenes in the order elsewhere described; and if a slight degree of aeration be accomplished, but still not enough for the necessities of the system, instead of suffocation, the individual dies more gradually; the functions fail in the same order; dark blood circulates through all the textures; hence lividity, especially of those parts where the cuticle is extremely thin, as of the lips, and wherever the mucous membranes commingle with the skin; the blood gradually becomes inadequate to keep up the action of the brain and nervous system generally, as well as to stimulate the heart, and the individual gradually expires. If, again, the blood, although properly converted in the lungs, be not duly distributed to the organs, owing to the failure of the circulatory powers,—either from direct or indirect causes,—the organs exhibit their correlation in the same manner, and syncope or fainting, or positive death, may be induced. Often, however, the stoppage of the action of the heart is but for a short time. Owing to some painful impression, sudden emotion, or other cause, the organ ceases to contract, either suddenly,—when the person falls down as if deprived of life,—or gradually, when the connection of the different functions, and the order in which they fail, are manifest. Of this kind of—what the surgeon calls—*morbid sympathy* or *constitutional irritation*, we have a good example in the effect of a trifling operation on a delicate, and often on a strong, individual. Bleeding induces fainting,—both directly, by the abstraction of fluid from the vessels, so that the brain may cease to act; and indirectly, when

the quantity removed cannot be presumed to have exerted any influence. Some, indeed, faint from the slightest puncture and loss of blood, or even from the sight of that fluid. In these last cases, if the syncope comes on gradually, a feeling of anxiety and oppression, occasionally of vacuity, exists in the epigastric region, perceptions become confused; the sight is obscured; tinnitus aurium and dizziness supervene; the respiration is embarrassed; the face pale; the extremities cold, and the different parts of the body are covered with a cold, clammy sweat, until, ultimately, loss of sensation and motion supervenes, and the individual is temporarily dead; from which state he soon recovers, in the generality of cases, provided he is kept in the recumbent posture, so that the blood may readily pass to the brain.

On other occasions, the heart does not cease its pulsations, but continues to send blood, in undue quantity, to the brain, so that all the above phenomena may ensue, except the temporary privation of vitality. In consequence of the severe pain induced by a displacement of two of the bones of the wrist, by a fall from a carriage, the author remained a considerable time incapable of sight, and at the same time suffering from great anxiety and oppression; yet consciousness and the action of the heart never ceased, as in complete syncope. The third vital function,—that of innervation,—when suspended or diminished, draws on a train of morbid phenomena in the order described under the head of Death; suspending respiration and circulation suddenly, if the cause applied be sufficient; more gradually, and with symptoms characterizing apoplexy or compression of the brain, if the cause act in a minor degree. All the three vital functions are consequently correlative, and so intimately associated, that if a malign influence act upon one, the effect is speedily extended to the other.

Owing to the necessity for the blood possessing certain attributes, the most important of which are obtained by its circulation through the lungs, we can understand, that if the functions of nutrition be not properly exerted, the composition of that fluid may be imperfect, and disorder take place in various parts of the frame from this cause. Thus, if digestion or the formation of chyle be not properly executed, the blood is not duly renovated, and may be so far impoverished, that the play of the functions is interfered with. We have elsewhere shown, that if omnivorous man be restricted to one kind of diet he will fall off, and become scorbutic, and that the affection may be removed by allowing him diet of another kind;—vegetables, if animal food has induced it; and conversely. Enlarged mesenteric glands, consequent, or not, on inflammation of the mucous membrane of the intestine, and the latter affection itself, are cases which may interfere with chylosis, and consequently, with the constitution of the blood. In like manner, if nutrition and the various secretions be not duly performed in the tissues of the organs, and, especially, if the great depurations be obstructed the blood may suffer; and although the due change from venous to arterial may be effected in the lungs, its character may not be such as to adapt it for the healthy execution of the various functions.

The humorists assigned too much importance to the humors in the production of disease; the solidists, on the other hand, have denied

them almost all agency. A medium between these exclusionists is probably the nearest to truth. The solitary fact of black blood being unfit to maintain the perfect and continued vitality of any organ sufficiently exhibits its influence. How the arterial blood exerts its agency, independently of its action as a fluid of nutrition, is beyond our knowledge. It appears to effect a necessary action of stimulation, but in what manner, or on what element, we know not: probably, however, its chief influence may be on the nervous tissue, as privation of arterial blood soon occasions the cessation of the brain's action.

In the higher classes of animals, innervation is dispensed from three great centres,—the encephalon, spinal marrow, and the great sympathetic. If the nervous supply be cut off from any part, the part dies. Physical integrity, continuity, and a due supply of arterial blood, are necessary to the proper exercise of the nervous power. In the former part of this work, the wonderful resistance to death which characterizes the amphibia, and the comparative independence of each portion of the body in some of the lower orders of animals, were pointed out. The polypus may be divided into numerous pieces, yet each may constitute of itself a distinct animal. The snail, after decapitation, reproduces the head; and a similar reparatory power is possessed by other animals. We have elsewhere seen, that volition is seated lower in the inferior than in the superior orders of animals; and that in man it is chiefly,—some say, wholly,—restricted to the encephalon. It appears, likewise, that the dependence of the rest of the nervous system on the great nervous centres is less in young than in old animals. M. Edwards regarded the new-born child as resembling, in many respects, the cold-blooded animal; and Redi, Rolando and Flourens, and Legallois, found that the tenacity of life, after decapitation, was much greater the nearer to birth. The functions also differ with regard to their dependence upon the encephalon. Disease may attack the animal functions and suspend them for a considerable length of time,—as in apoplexy,—before the organic functions are interfered with. The cerebro-spinal nervous system may cease to act, and life continue; but if the true spinal or reflex nervous system has its action suspended, respiration ceases, and death is inevitable. This is a topic, however, which will be discussed under the head of Death.

A gifted preceptor of the author,—the late Professor Béclard,[1]—has defined life to "consist essentially in the reciprocal action of the circulation of the blood and innervation; death always following the cessation of such reciprocal action." But this conclusion is applicable only to animals; although both circulation and innervation are admitted in the vegetable by some physiologists. M. Legallois,[2] from his experiments, deduced the unwarrantable inference, that "life is owing to an impression made by arterial blood on the brain and spinal marrow, or to the principle, which results from this impression;"—a definition, that would exclude the numerous animals of the lower classes, as well as vegetables, which are deficient in both brain and spinal marrow.

[1] Elémens d'Anatomie Générale, 2de édit., Paris, 1827; or Togno's translation, p. 106, Philad., 1830.

[2] Sur le Principe de la Vie, Paris, 1812.

Some have endeavoured to discover which of the two functions,—circulation or innervation,—holds the other in domination. They, who consider the nervous substance to be first formed in the fœtus, ascribe the supremacy to it; whilst the believers in the earlier formation of the sanguiferous system look upon it as the prime agent. We know no more than that both

> "Maintain,
> With the mysterious mind and breathing mould,
> A co-existence and community."

Matter is, however, endowed with life, independently of the functions mentioned, as in the case of the materials furnished by both parents at a fecundating copulation; to which no one can deny the possession of a Trieb, impulse or life-power, before there are organs of either circulation or innervation.

In every important function of the body we find the correlation of organs existing,—all working to one end, and all requisite for its perfect accomplishment. How many organs, for example, are required to co-operate in the elevated function of sensibility! The encephalon, the seat of thought, receives, by the external senses, the various impressions that act upon them from without, and, by the internal sensations, such as arise in the economy, and are the indexes of physical necessities or wants. The intellectual and affective faculties enable us to appreciate the various objects that occasion our sensations, and to indicate our social and moral wants: under their direction, volition is sent out, which acts upon the various muscles, and produces such movements as may be required for carrying into effect the suggestions of the mind. Between all these acts there is the closest catenation. In like manner, we observe the correlation between the animal, nutritive, and reproductive functions. The internal sensation of hunger suggests to the mind the necessity for a supply of aliment; the external senses are called into action to discover the proper kind; when discovered, it is laid hold of by muscular movements under the direction of volition; is subjected to various voluntary processes in the mouth, and then passed on, by a mixed voluntary and involuntary action, into the stomach. In like manner, the desire for sexual intercourse may be excited through the organs of vision or touch; the organs of generation are aroused to action, and the union of the sexes is accomplished by the exertion of muscles thrown into contraction by volition. The same catenation is exhibited after a fecundating copulation; menstruation, which was previously performed with regularity, is arrested; the breasts become developed; milk is formed in them; and, whilst the female suckles her child, unless the period is unusually protracted, the arrest of the menstrual functions continues.

Almost all the phenomena of disease are connected with this correlation of functions. Derangement takes place in one organ or structure of the body, and speedily all those that are correlated with it participate in the disorder. Hence, in part, arises the combination of disordered nervous, circulatory, and secretory function, which characterizes general fever, and the various associated morbid actions that constitute disease in general.

3. SYMPATHY.

There is another kind of connexion, which distinguishes the animal body from a piece of ordinary mechanism still more than those we have considered. In this, owing to an impression made upon one organ, distant organs become affected, without our being able to refer the transmission to mechanical agency, or to the association of functions, which we have described. This kind of association is called *sympathy*. A particle of snuff or other irritating substance, impinging on the Schneiderian membrane, produces itching there, followed by a powerful action of the whole respiratory apparatus, established for its removal. The sneezing, thus induced, is not caused by the transmission of the irritation through the intermediate organs to the respiratory muscles; nor can we explain it by the mechanical or functional connexions of organs. It is produced by this third mode of correlation:—or by sympathy. Again, a small wound in the foot produces locked jaw, without our being able to discover, or to imagine, any greater connexion between the foot and the jaw, than between the foot and other organs of the body. We say, that this is caused by sympathy between these organs, and, so long as we use the term to signify the unknown cause of such connexions, it is well. It must be understood, however, that we attach no definite idea to the term; that it is only employed to express our ignorance of the agent or its mode of action; as we apply the epithet *vital* to a process, which we are incapable of explaining by any physical facts or arguments.

Of sympathetic connexions we have numerous examples in the body; at times, inservient to accomplishing a particular function; but generally consisting of modifications of function produced by the action of a distant organ. Of the sympathetic connexion between the parts of the same organ, for the execution of a function proper to that organ, we have an example in the iris and retina: the former contracts or dilates according to the degree of stimulation exerted by the light on the latter; and the effect is greater when the light is thrown on the retina than on the iris itself. A similar kind of sympathy exists between the mammæ and uterus, during pregnancy, although this has been frequently referred to ordinary functional correlation or synergy; but the connexion is sufficiently obscure to entitle it to be placed under this division. A singular example of the sympathy between these two organs, soon after delivery, is the fact of the sudden and powerful contraction excited in the uterus, when in a state of inertness, by the application of the child to the breast.

a. *Sympathy of Continuity.*

This occurs between various parts of membranes that are continuous. For example, the slightest taste or smell of a nauseous substance, may bring on an effort to vomit,—the whole of the first passages being unfavourably disposed for its reception. In disease, we have many examples of this kind of sympathy. During dentition, the child is subject to various gastric and intestinal affections. If a source of irritation exists in any part of the intestinal or other mucous membrane, no uneasy

sensation may be experienced in the seat of irritation, yet it may be felt at the commencement of the membrane or where it commingles with the skin:—thus, itching at the nose may indicate irritation of the digestive mucous membrane;—itching or pain of the glans penis, stone in the bladder, &c. These facts prove, that, in disease, a sympathetic bond unites the parts concerned; and such is probably the case in health also. We have the same thing proved in the effect produced on the action of glands by irritating the orifices of their excretory ducts. The presence of food in the mouth excites the secretion of the salivary glands, and that of chyme in the duodenum augments the secretion of the liver. In the same manner, a purgative, as calomel, which acts upon the upper part of the intestinal canal, becomes a cholagogue; and duodenal irritation occasions a copious biliary secretion. These cases have, however, been considered by many to belong more appropriately to functional correlation; as it is presumable, that the propagation of the irritation from the orifice of the excretory duct takes place directly, and along branches of the same nerves as those that supply the glandular organs in question.

It is by the sympathy of continuity that we explain the action of certain medicines. In bronchial irritation, for example, the cough is frequently mitigated by smearing the top of the larynx with a demulcent,—the soothing influence of which extends to the part irritated.

b. *Sympathy of Contiguity.*

A variety of sympathy, differing somewhat from this, is the *sympathy of contiguity* or *contiguous sympathy*, in which an organ is affected by an irritation seated in another immediately contiguous to it. The association of action between the lining membrane of the heart and the muscular tissue of the organ has been given as an instance of this kind; and chiefly from the experiments of MM. Bichat and Nysten, which showed, that any direct irritation of the muscular tissue of the heart has not as much influence as irritation of the membrane that lines it. A similar association is presumed to exist between the mucous and muscular coats of the alimentary canal; and the same kind of evidence is adduced to prove that the connexion is sympathetic. Other instances of sympathy are,—the convulsive contraction of the diaphragm and abdominal muscles in vomiting consequent on the condition of the stomach, as well as the convulsive action of the respiratory muscles in sneezing, coughing, &c. The general uniformity in the motion of the two eyes has been given as an additional instance; but M. Adelon[1] has judiciously remarked, that the evidence in favour of this view is insufficient. For clearness of vision it is necessary, that the luminous rays should impinge upon corresponding points of the two retinæ, and should fall as nearly as possible in the direction of the optic axes. For this purpose, the muscles direct the eyes in the proper manner; and subsequently, from habit, the balls move in harmony. We constantly hear, also, a fact taken from pathology as an instance of sympathy. A molar tooth is lost on one side of the jaw; and it is found that the next tooth which

[1] Physiologie de l'Homme, edit. cit., iv. 267, Paris, 1829

decays is the corresponding molar of the opposite side:—or a tooth has become carious, and we find the one next to it soon afterwards in a course of decay. These have been regarded as evidences of sympathy,—remote and contiguous. This is not probable. The corresponding teeth of the two sides are similarly situate as regards the supply of nerves, vessels, and every anatomical element; and experience teaches us, that the molar teeth—and especially the second great molares—decay sooner than others. If one, therefore, becomes carious, we can understand why its fellow of the opposite side should be more likely to suffer. The opinion, that contiguous teeth are likely to be affected by the presence of a carious tooth, either by sympathy, or direct contact, is almost universally believed, and promulgated by the dentist. Both views are probably alike erroneous. If the inner side of the second molaris be decayed, we can understand why the corresponding side of the third should become carious, without having recourse either to the mysterious agency of sympathy, or to the very doubtful hypothesis of communication by contact,—especially as the caries generally begins internally. The contiguous sides of the teeth are situate almost identically as regards their anatomical elements; and, consequently, if a morbid cause affects the one, the other is more likely to suffer, and very apt to do so. Extracting the diseased tooth prevents this, because it removes a source of irritation, which could not but act in a manner directly injurious on the functions of the tooth next to it.

The fact of the sympathy that exists between organs of analogous structure and functions, is familiar to every pathologist. That of the skin and mucous membrane is intimate. In every exanthematous disease, the danger is more or less dependent upon the degree of affection of the mucous membranes; and the direct rays of the sun, beaming upon the body in warm climates, in this manner induce diarrhœa and dysentery. Acute rheumatism is a disease of the fibrous structures of the joints; but one of its most serious extensions, or metastases,—whichsoever they may be considered,—is to the fibrous structure of the pericardium. M. Barthez,[1] a most respectable writer, gives a case of this kind of sympathy from Theden, which is inexplicable and incredible. A patient, affected with paralysis of the right arm, applied a blister to it, which produced no effect, but acted on the corresponding part of the other arm. The left becoming afterwards paralysed, a blister was put upon it, which also acted upon the other arm, not on the one to which it was applied! Owing to the sympathy, or consent of parts, M. Broussais[2] has laid down the pathological law,—that when an irritation exists for a long time in an organ, textures analogous to the one diseased, are apt to contract the same affection.

c. *Remote Sympathies.*

As examples of the more remote kinds of sympathy, we may cite the effect produced on the stomach by distant organs, and conversely. Among the earliest signs of pregnancy are nausea and vomiting; loath-

[1] Nouveaux Elémens de la Science de l'Homme, Paris, 1806.

[2] Commentaires des Propositions de Pathologie; and Drs. Hays' and Griffith's translation, p. 60, Philada., 1832.

ing of food; fastidious appetite, &c. These phenomena are manifestly induced by sympathetic connexion between the uterus and stomach; inasmuch as they are not adventitious, but occur, more or less, in all cases of pregnancy. Their absence, at least, is a rare exception to the rule. Hunger or dyspepsia, again, impresses a degree of languor,—mental and corporeal,—which is proverbial; whilst the reception of food, and its vigorous digestion, give a character of energy and buoyancy, greatly contrasting with opposite circumstances. In disease, too, we find sympathies existing between the most distant portions of the frame, and although these are not apparent in health, we are perhaps justified in considering, that an occult sympathy exists between them in health, which only becomes largely developed, and obvious, when the parts are affected with disease. It is probable, too, that in the successive evolution of organs at different periods of life, new sympathies arise, that did not previously exist or were not observable. The changes in the whole economy at puberty illustrate this; changes that do not occur in those who, owing to malformation, are not possessed of the essential parts of the reproductive system, or who have had them removed prior to this period.

d. *Imagination.*

The effect of the intellectual and moral faculties on the exercise of the functions of other parts is strongly evidenced, especially in disease. The influence of the mind over the body is, indeed, a subject that demands the attention of every pathologist. In health, we notice the powerful effect induced by the affective faculties on every function. All these are caused by sympathetic association with the brain; the action of the organs being in a state of excitement or depression, according to the precise character of the emotion. The intellectual manifestations probably exert their influence in a manner less evident, but not less certain. The effects of one of them, at least, on the bodily functions are remarkable. We allude to the *imagination*, to which we can ascribe most of the cures said to have been effected by modes of management,—often of the most disgusting character,—which have been from time to time in vogue; have fretted their hour on the stage, and then sunk into that insignificance from which they ought never to have emerged.

Occasion has been had to allude to the excited imagination of the maniac, the hypochondriac, and the nervous, and it was remarked, that hallucinations may exist in those of sound mind;—phantoms created by the imagination; pains felt in various bodily organs, &c.; and we can hence understand, that, under special circumstances, we may have actual disease produced in this manner; and, at other times, the feeling,—which may be as distressing to the patient,—of disease, which has no existence except in the imagination. It is to the effect produced by the imagination, that we must ascribe the introduction into medicine of magic, sorcery, incantations, Perkinism, and other offsprings of superstition or knavery. The enthusiasm, that has attended the application of these modes of acting on the imagination in our own times, is extraordinary, and their history leads us to be still more impressed

with the extensive influence that may be exerted by the mind over the body: they teach the practitioner the importance of having its co-operation, whenever it can be procured; and the disadvantages, which he may expect to ensue, when the imagination is either arrayed against himself personally, or the plan of treatment he is adopting. The physician, who has the confidence of his patient, may be successful—if he adopts precisely the same plan of treatment that would be pursued by one who has it not—in cases where the latter would totally fail. The applications of this subject are developed by the author elsewhere.[1]

Again, pathology is invoked as affording us perhaps the best evidences of the existence between various parts of the frame of extensive sympathetic relations, that may be constantly going on unseen during health, but become developed, and obvious in disease. The case, previously given, of the general effects produced on the system by local irritation of a part, shows the extent of such association. An insignificant portion of the body may become inflamed, and if the inflammation continues, the functions of the stomach may be disordered,—as indicated by loss of appetite, nausea, and vomiting; the respiration be hurried, as well as the circulation; the senses blunted; the intellectual and moral faculties obscured; and languor and lassitude indicate the nervous irritation and constraint.

The moral consideration of sympathy does not immediately concern the physiologist. It is a subject,—and one of interest,—to the moral philosopher, to account not only for the secret causes, that attract individuals towards each other, but that repel them and occasion *antipathies*. To a certain extent, however, it trends into the province of the physiologist. The tender, susceptible individual, from observing another suffering under pain, feels as if labouring under the same inconvenience; and, by a very rapid, yet complex intellectual process, constituted of numerous associations, may be so strongly impressed as to sink under their influence:—thus, the sight of blood so powerfully impresses the mind of some, in this sympathetic manner, that fainting may be induced, and the vital functions be for a time suspended. The sight and suffering of a woman in labour may cause abortion in another; and hence the propriety of excluding those who are pregnant from the chamber of the parturient female. Hysteric and convulsive paroxysms are induced in a similar way; of which the *convulsionnaires* of all times must be regarded as affording singular and instructive examples.

e. *Superstitions connected with Sympathy.*

Lastly:—The mysterious consent, observed between various parts of the body, has given rise to some strange and absurd superstitions. It was believed, for instance, almost universally, in the fifteenth century, that an intimate sympathy exists, not only between parts of a body forming portions of one whole, but also between any substance that had previously formed part of a body and the body itself;—that if, for example, a piece of flesh were sliced from the arm of one person, and made to unite with that of another, the grafted portion would

[1] General Therapeutics and Materia Medica, 4th edit., Philada., 1850.

accurately sympathize with the body of which it had previously formed part, and undergo decay and death along with it; and it was even proposed to turn this sympathy to account. It was recommended, for instance, that the alphabet should be traced on the ingrafted portion; and it was affirmed, that when any of the letters, so traced, were touched, the party from whom the piece of flesh had been taken would feel similar impressions; so that, in this manner, a correspondence might be maintained. Some went even farther than this, asserting, that such a miraculous sympathy exists between the human body and all that has previously formed part of it, that if a hot iron were run into the excrement, he would feel a sensation of burning in the part whence it had proceeded!

It was also a notion, that grafts of flesh, united to the body of another, died when the person died from whom they had been taken. In a work on animal magnetism, the case of a man at Brussels is given, who had an artificial nose formed after the old Taliacotian method, which served every useful purpose, until the person, from whom the graft had been taken, died, when it suddenly became cold and livid, and fell off. Tagliacozzi[1] himself lived in an era of superstition, when this belief in the simultaneous death of the parent and graft was universally credited; and the folly has not escaped the notice of Butler:

"So learned Taliacotius from
The brawny part of porter's bum,
Cut supplemental noses, which
Would last as long as parent breech;
But when the date of nock was out,
Off dropped the sympathetic snout."—*Hudibras.*

But the power of sympathy has been conceived to extend farther. The magical influence of the will of one person over another was credited by such men as Bacon, who lived in the very era of luxuriant superstition, and the belief has been resuscitated at the present day. It has been credited, for example, that when a person is in a magnetic or mesmeric state, it is but necessary for the magnetizer to will that the magnetized person shall execute some act, and it is immediately accomplished. Nay, that a magnetized individual may be taken at the will of one, with whom he is placed in communion or *rapport*, to a distance, and describe scenes and objects, which he had never witnessed, exactly as those scenes and objects really are; taste, smell, feel, and see objects, that are tasted, smelt, felt, and seen by another; and be wafted even to "any or all the heavenly bodies of which we have any knowledge;" and it has been gravely affirmed by a veteran teacher[2] in his enthusiasm on the subject, that "such deeds as these may well be called amazing, yet are they as easy, certain, and speedy of performance, as many of the most common transactions of life." Yet the evidence is totally insufficient to establish the existence of the slightest shade of such mysterious sympathy![3]

Not less singular was the superstition,—that the wounds of a mur-

[1] Gasparis Taliacotii Bononiensis De Curtorum Chirurgiâ per insitionem libri duo, Venet., 1597.

[2] Caldwell, Facts in Mesmerism, and Thoughts on its Causes and Uses, Louisville, 1842.

[3] The Author's Medical Student, new edit., p. 250, Philad., 1844.

dered person will bleed afresh if the body be touched ever so lightly, in any part, by the murderer. This idea gave rise to the trial by *bier-right*, which has been treated by Sir Walter Scott with so much dramatic skill in one of his novels,—*St. Valentine's Day, or the Fair Maid of Perth.* The annals of judicial inquiry furnish us with many instances of this gross superstition.[1] A case of the kind occurred in this country. It is stated in the attestation of John Demarest, coroner of Bergen county, New Jersey.[2] The superstition is noticed, too, by many of the older poets. Thus, Shakspeare,—where the Lady Anne reviles Gloster over the corpse of Henry:—

> "O! gentlemen, see, see! dead Henry's wounds
> Open their congeal'd mouths and bleed afresh!
> Blush, blush, thou lump of foul deformity;
> For 'tis thy presence that exhales this blood
> From cold and empty veins, where no blood dwells.
> Thy deed, inhuman and unnatural,
> Provokes this deluge most unnatural."
>
> RICHARD III., i. 2.

And Webster, in a tragedy published about the middle of the seventeenth century:—

> "See
> Her wounds still bleeding at the horrid presence
> Of yon stern murderer, till she find revenge."
>
> APPIUS AND VIRGINIA.

The belief in these cases of monstrous superstition, which, it need scarcely be said, are explicable on purely physical principles, or on the excited imagination of observers, still exists amongst the benighted inhabitants of many parts of Great Britain and Ireland, and is the main topic of one of the second series of "*Traits and Stories of the Irish Peasantry.*" The superstition has, indeed, its believers among us. On the trial of Getter, who was executed in 1833 in Pennsylvania, for the murder of his wife, a female witness deposed on oath, as follows:—"If my throat was to be cut, I could tell, before God Almighty, that the deceased smiled, when he (the murderer) touched her. I swore this before the justice, and that she bled considerably. I was sent for to dress her and lay her out. He touched her twice. He made no hesitation about doing it. I also swore before the justice, that it was observed by other people in the house."

It would be endless to enumerate the various superstitions, that have prevailed on topics more or less remotely connected with this subject. We pass on to the interesting, but abstruse, inquiry into the

f. *Agents by which Sympathy is accomplished.*

The opinions of physiologists have, from time to time, rested chiefly on the membranes, areolar tissue, bloodvessels, and nerves; but there have been some, who, in the difficulty of the subject, have supposed sympathy to be devoid of organic connexion; and others, again, have

[1] See the case of Philip Stansfield for the Murder of his Father, Sir James Stansfield, in Hargrave's State Trials, iv. 283; and in Celebrated Trials of all Ages, &c., ii. 566. Lond., 1825.

[2] Annual Register, for 1767.

presumed, that all the parts mentioned are concerned. The rapidity, however, with which sympathies are evidenced, has led to the abandonment of all those opinions; and the generality of physiologists of the day look to the nervous system as the great source and medium of communication of the different irradiations by which distant organs are supposed to react, in this manner, on each other. The rapidity, indeed, with which the various actions of the nervous system are executed,—the apparent synchronism between the reception of an impression on an organ of sense, and its perception by the brain; as well as between the determination of the will and its effect upon a muscle,—naturally attracted attention to this system as the instrument of sympathy.

The modes, in which sympathy is supposed to be accomplished, are;—either by the parts that sympathize receiving ramifications from the same nervous trunks, or from such as are united by nervous anastomoses; or, by the nervous irradiations, emanating from one organ, proceeding to the brain, and being thence reflected to every dependency of the system, but in such sort, that certain organs are more modified by the reflection than others; hence, the distinction into what have been termed *direct sympathies* and *cerebral sympathies*.

Of direct sympathies we have already given examples,—as that between the mucous and muscular coats of the intestines; and if our acquaintance with the precise distribution and connexion of the various parts of the nervous system were more intimate, we might perhaps explain many of the cases that are yet obscure. The researches of Sir Charles Bell regarding the nerves concerned in respiration have thrown light on the associations of organs in the active exercise of the respiratory function. It has been elsewhere shown, that although the whole of the nerves, composing his *respiratory system*, may not be apparently in action during ordinary respiration, yet when the function has been greatly excited, the association becomes obvious. The opinion of Boerhaave, Meckel, and some others, is, that all sympathies are accomplished in this direct manner. On the other hand, Haller, Whytt, Georget, Broussais, Adelon, and others, think, that the majority of sympathies are produced through the medium of the brain. Dr. Bostock[1] indeed affirms, that the facts, adduced by Whytt,[2] are of such a nature as "to prove, that the co-operation of the brain is essential in those actions, which we refer to the operation of sympathy." In many cases, this is, doubtless, the fact;—as in sneezing and coughing; but there are others in which such co-operation seems improbable and indeed impossible. Something like sympathy exists in the vegetable; in which if we admit, with some naturalists, a rudimental nervous system, we have no reason for presuming, that there is any thing like a centre for the reception or transmission of impressions, and the case of infants born devoid of brain and spinal cord affords evidence of a like description.

We find, that the influence of the vital principle is exemplified in the formation of a body of a certain magnitude, form, structure, composi-

[1] Elementary System of Physiology, 3d edit., p. 762, Lond., 1836.

[2] An Essay on the Vital and other Involuntary Functions, § xi., Edinb., 1751.

tion and duration; and that this applies to all organized bodies, vegetable as well as animal. Where such appearance of design, consequently, exists, we ought to expect, that in the vegetable, also, a harmony or consent must reign amongst the various functions that tend to the production of the uniformity, which enables us to recognise the particular varieties of the vegetable kingdom, and has kept them as distinct, probably, in their characters, as when first created by Almighty power. The irritation of a single leaflet of the *Mimosa pudica* or *sensitive plant* causes the whole leaf, as well as the footstalk, to contract. Dr. John Sims irritated a leaflet of this plant, taking the greatest pains to avoid moving any other part of the leaf; yet the whole contracted, and the footstalk dropped. In order, however, to be sure, that mechanical motion communicated by the irritation had no share in the contraction, he directed a sunbeam, concentrated by a lens, on one of the leaflets, when the leaf again contracted, and the footstalk dropped. Of this kind of vegetable irritability we have many examples, some of which are alluded to under another head.

From these and other facts of an analogous character, Sir Gilbert Blane[1] concludes, that the functions of living nature, in all its departments, are kept up by a mutual concert and correspondent accordance of every part with every other part;—that it would be in vain to waste time in endeavouring to account for them by groping among dark analogies and conjectures; and that it is better to assume them as facts, on which are founded the ultimate and inscrutable principles of the animal economy. We have certainly much to learn regarding the agents of sympathies, and the modes in which they are effected; but still we know enough to infer, that in many cases, in animals, the nerves appear to be the conductors; that the brain is, in others, the centre to which the organ in action transmits its irradiations, and by which they are reflected to the sympathizing organ; and that in others, again, the effect is caused in the absence of nervous centre, and even of nerves, by vibrations perhaps, but in a manner which, in the present state of our knowledge, is inexplicable, and is, therefore, supposed to be essentially *organic* and *vital*,—epithets, however, as we have more than once said, that merely convey a confession of our ignorance of the processes to which they are appropriated.

CHAPTER IV.

INDIVIDUAL DIFFERENCES AMONGST MANKIND.

The differences observed amongst the individuals of the great human family are as numerous as the individuals themselves; but this dissimilarity is not confined to man or to the animal kingdom: the vegetable exhibits the same; for, whilst we can readily refer any plant to the species and variety, to which it may have been assigned by the botanist, accurate inspection shows that in the precise arrangement of

[1] Elements of Medical Logic, 3d edit., Lond., 1819.

the stalk, branches, leaves, or flowers, no two are exactly alike. We shall not, however, dwell on these trifling points of difference, but restrict ourselves to the broad lines of distinction, that can be easily observed, and an attention to which is of some moment to the physician. Such are the *temperaments*, *constitutions*, *idiosyncrasies*, *acquired differences*, and *varieties of the human species* or the *different races of mankind*. Of these, the last belong more especially to the natural historian; and, consequently, will be but briefly noticed.

1. TEMPERAMENTS.

The temperaments are defined to be,—those individual differences, which consist in such disproportion of parts, as regards volume and activity, as to modify sensibly the whole organism, but without interfering with the health. Temperament is, consequently, a physiological condition, in which the action of the different functions is so *tempered* as to communicate certain characteristics, that may be referable to one of a few divisions. These divisions are by no means the same in all physiological treatises. The ancients generally admitted four,—denominated from the respective fluids or humours, the superabundance of which in the economy was supposed to produce them;—the *sanguineous*, caused by a surplus of blood; the *bilious* or *choleric*, produced by a surplus of yellow bile; the *phlegmatic*, caused by a surplus of phlegm, lymph, or fine watery fluid, derived—it was conceived—from the brain; and the *atrabiliary* or *melancholic*, produced by a surplus of black bile,—the supposed secretion of the atrabiliary capsules and spleen. This division was kept up for ages without modification; and still prevails with one or more additional genera. The epithets have been retained in popular language without our being aware of their parentage. For example, we speak of a *sanguine*, *choleric*, *phlegmatic*, or *melancholic* individual or turn of mind with nearly the acceptation given to them by the Hippocratic school,—the possessors of these temperaments being presumed to be, respectively, full of high hope and buoyancy; naturally irascible, dull and sluggish; or gloomy and low-spirited. Metzger admits only two,—the *irritable* (reizbare), and the *dull* or *phlegmatic* (träge). Wrisberg[1] eight,—the *sanguine*, *sanguineo-choleric*, *choleric*, *hypochondriac*, *melancholic*, *Bœotian*, *meek*, (sanftmüthige,) and the *dull* or *phlegmatic*. Rudolphi[2] also eight,—the *strong* or *normal;* the *rude*, *athletic* or *Bœotian;* the *lively;* the *restless;* the *meek;* the *phlegmatic* or *dull;* the *timorous*, and the *melancholic;*—whilst M. Broussais[3] enumerates the *gastric*, *bilious*, *sanguine*, *lymphatico-sanguineous*, *anæmic*, *nervous*, *bilioso-sanguine*, *nervoso-sanguine*, and *melancholic*. It is obvious, that if we were to apply an epithet to the possible modifications caused by every apparatus of organs, the number might be extended much beyond any of these. Perhaps the division most generally adopted is

[1] In his edition of Haller's Grundriss der Physiologie.
[2] Grundriss der Physiologie, 1er Band., s. 258, Berlin, 1821.
[3] Traité de Physiologie, Drs. Bell's and La Roche's translation, 3d edit., p. 561, Philad., 1832.

that embraced by M. Richerand,[1] who has embodied considerable animation, with much that is fanciful, in his description. In this division, the ancient terms have been retained, whilst the erroneous physiological basis, on which they rested, has been discarded. A short account of these temperaments is necessary, rather for the purpose of exhibiting what has been, and is still, thought by many physiologists, than for attesting the reality of many of the notions that are mixed up with the subject. With this view, the temperaments may be divided into the *sanguine*, *bilious* or *choleric*, *melancholic*, *phlegmatic*, and *nervous*.

a. *Sanguine Temperament.*

This is supposed to be dependent upon a predominance of the circulatory system; and hence is considered to be characterized by strong, frequent, and regular pulse; ruddy complexion; animated countenance; good shape, although distinctly marked; firm flesh; light hair; fair skin; blue eyes; great nervous susceptibility, attended with rapid *successibilité*, as the French term it; that is,—a facility of being impressed by external objects, and passing rapidly from one idea to another; quick conception; ready memory; lively imagination; addiction to the pleasures of the table; and amorousness. The diseases of this temperament are generally violent; and chiefly implicate the circulatory system,—as fevers, inflammations, and hemorrhages. Its physical traits, according to M. Richerand, are to be found in the statues of Antinous and the Apollo Belvidere: the moral physiognomy is depicted in the lives of Mark Antony and Alcibiades. In Bacchus, both the forms and character are found; and no one in modern times, in M. Richerand's opinion, exhibits a more perfect model of it than the celebrated Duke de Richelieu;—amiable, fortunate and valorous, but light and inconstant to the termination of his brilliant career.

If individuals of this temperament apply themselves to labours of any kind that cause the muscles to be greatly exerted, these organs become largely developed, and a subdivision of the sanguine temperament is formed, which has been called the *muscular* or *athletic*. This is characterized by all the outward signs of strength: the head is small; the neck strong; the shoulders broad; the chest large; the hips solid; the muscles prominent, and the interstices well marked. The joints, and parts not covered with muscles, seem small; and the tendons are easily distinguished through the skin by their prominence. The susceptibility to external impressions is not great; the individual is not easily roused; but when he is, he is almost indomitable. A combination of the physical powers, implied by this temperament, with strong intellect, is rarely met with.

The Farnesian Hercules is conceived to offer one of the best specimens of the physical attributes of the athletic temperament.[2]

[1] Nouveaux Elémens de Physiologie, 13ème édit. par M. Bérard ainé, § ccxxviii., Bruxelles, 1837.

[2] Richerand, op. citat., § ccxxix.

b. *Bilious* or *Choleric Temperament.*

This is presumed to be produced by a predominance of the liver and biliary organs. The pulse is strong, hard, and frequent; the subcutaneous veins are prominent; the skin is of a brown colour inclining to yellow; hair dark; body moderately fleshy; muscles firm, and well marked; passions violent, and easily excited; temper abrupt and impetuous; great firmness and inflexibility of character; boldness in the conception of projects, and untiring perseverance in their fulfilment. It is amongst the possessors of this temperament, that the greatest virtues and the greatest crimes are met with. The moral faculties are early developed; so that vast enterprises may be conceived, and executed at an age when the mind is ordinarily far from being matured. The diseases are generally combined with more or less derangement of the hepatic system. The whole of the characters, however, indicate, that an excited state of the sanguiferous system accompanies that of the biliary organs; so that the epithet *cholerico-sanguine* might, with more propriety, be applied to it. Where this vascular predominance does not exist, and derangement is present in some of the abdominal organs, or in the nervous system, we have the next form produced.

M. Richerand[1] enumerates Alexander, Julius Cæsar, Brutus, Mahomet, Charles XII., Peter the Great, Cromwell, Sextus V., and the Cardinal Richelieu. To these, Dr. Good[2] has added Attila, Charlemagne, Tamerlane, Richard III., Nadir Shah, and Napoleon.

c. *Melancholic* or *Atrabilious Temperament.*

Here the vital functions are feebly or irregularly performed; the skin assumes a deeper hue; the countenance is sallow and sad; the bowels are torpid; and all the excretions tardy; the pulse is hard, and habitually contracted; the imagination gloomy, and the temper suspicious. The characters of Tiberius and of Louis XI. are considered to be examples of predominance of this temperament; and, in addition to these, M. Richerand[3] has enumerated Tasso, Pascal, Gilbert, Zimmermann, and Jean Jacques Rousseau.

d. *Phlegmatic*, *Lymphatic* or *Pituitous Temperament.*

In this case, the proportion of the fluids is conceived to be too great for that of the solids;—the secretory system appearing to be active, whilst the absorbent system does not act so energetically as to prevent the areolar texture from being filled with humours. The characteristics of the temperament are:—soft flesh; pale skin; fair hair; weak, slow, and soft pulse; figure rounded, but inexpressive: vital actions more or less languid; memory by no means tenacious; attention vacillating; with aversion to both mental and corporeal exertion. Pomponius Atticus—the friend of Cicero—is offered as an example of this temperament, in ancient times; Montaigne, in more recent. The latter, however, possessed much of the nervous susceptibility that characterizes the more lively temperaments. Dr. Good[4] suggests the Emperor

[1] Op. cit., § ccxxx.
[2] Book of Nature, 3d edit. iii. 276, Lond., 1834.
[3] Op. citat., ccxxxi.
[4] Op. citat., iii. 280.

Theodosius as an example in earlier times; and Charles IV. of Spain, who resigned himself almost wholly into the hands of Godoy,—Augustus, King of Saxony, who equally resigned himself into the hands of Napoleon,—and Ferdinand of Sicily, who surrendered for a time the government of his people to the British,—as instances in our own day. It would not be difficult to find amongst the crowned heads of Europe, others that are equally entitled to be placed amongst these worthies.

e. *Nervous Temperament.*

Here the nervous system is greatly predominant; the susceptibility to excitement from external impressions being unusually developed. Like the melancholic temperament, however, this is seldom natural or primitive. It is morbid or secondary, being induced by sedentary life, sexual indulgence, or morbid excitement of the imagination from any cause. It is characterized by small, soft, and, as it were, wasted muscles; and generally, although not always, by a slender form; great vividness of sensation; and promptitude and fickleness of resolution and judgment. This temperament is frequently combined with some other. The diseases that are chiefly incident to it are of the hysterical and convulsive kind; or those to which the epithet *nervous* is usually appropriated. Voltaire and Frederick the Great are given by M. Richerand[1] as examples of it.

Such are the temperaments described by most writers. The slightest attention to their reputed characteristics shows the imperfection of their definition and demarcation; so imperfect, indeed, are they, that it is extremely rare to meet with an individual, whom we could unhesitatingly refer to any one of them. They are also susceptible of important modifications by climate, education, &c., and may be so combined as to constitute innumerable shades. The man of the strongest sanguine characteristics may, by misfortune, assume all those that are looked upon as indexes of the melancholic or atrabilious; and the activity and impetuosity of the bilious temperament may, by slothful indulgence, be converted into the lymphatic or phlegmatic. It is doubtful, and more than doubtful, also, whether any of the mental characteristics assigned to the temperaments are dependent upon them. The brain, we have elsewhere seen, is the organ of the mental and moral manifestations; and although we may look upon the temperaments as capable of modifying its activity, they cannot probably affect the degree of perfection of the intellect;—its strength being altogether dependent upon the morphology of the brain. It is even doubtful whether the temperaments can interfere with the activity of the cerebral functions. In disease of the hepatic, gastric, or other viscera we certainly see a degree of mental depression and diminished power of the whole nervous system; but this is the effect of a morbid condition, and continues only so long as such morbid condition endures. Nor is it probable, that any predominance of the nutritive functions could exert a permanent influence on the cerebral manifestations. Whatever

[1] Op. cit., ccxxxiii.

might be the effect for a while, the nervous system would ultimately resume the ordinary action that befitted its primitive organization. Similar reasons to those have induced the author's late friend, M. Georget,[1]—a young physician of great promise and experience in mental affections, now no more,—to consider the whole doctrine of the temperaments as a superstition connected with the humoral pathology, and to believe, that the brain alone, amongst the organs, has the power, by reason of its predominance or inferiority, to modify the whole economy. That a difference of organization exists in different individuals is obvious; but that there is an arrangement of the nutritive organs or apparatuses, which impresses upon individuals all those mental and other modifications known under the name of temperaments, is, we think, sufficiently doubtful.

The *constitution* of an individual is the mode of organization proper to him. A man, for example, is said to have a robust, or delicate, or a good, or bad constitution, when he is apparently strong or feeble, usually in good health, or liable to frequent attacks of disease. The varieties in constitution are, therefore, as numerous as the individuals themselves. A strong constitution is considered to be dependent upon the due developement of the principal organs of the body, on a happy proportion between those organs, and on a fit state of energy of the nervous system; whilst the feeble or weak constitution results from a want of these. Our knowledge, however, of these topics, is extremely limited, and concerns the pathologist more than the physiologist.

2. IDIOSYNCRASY.

The word *idiosyncrasy* is used by many physiologists synonymously with constitution: but it is generally appropriated to the peculiar disposition, that causes an individual to be affected by extraneous agents, in a way in which mankind in general are not acted upon by these agents.

> "Some love not a gaping pig,
> And others, when the bagpipe sings i' th' nose,
> Cannot contain their urine for affection."
>
> SHAKSPEARE.

In all cases, perhaps, these peculiarities are dependent upon inappreciable structure, either of the organ concerned, or of the nervous branches distributed to it; at times, derived from progenitors; at others, acquired,—and often by association,—in the course of existence. Hence arise many of the antipathies to particular animate and inanimate objects, which we occasionally meet with, and of which M. Broussais relates a singular instance in a Prussian captain, whom he saw at Paris in 1815. He could not bear the sight of a cat, a thimble, or an old woman, without becoming convulsed, and making frightful grimaces! The associations must have been singularly complicated to occasion an antipathy to objects differing so signally from each other. Wagner,[2] of Vienna, has collected a multitude of cases of idiosyncrasy;

[1] De la Physiologie du Système Nerveux, &c., Paris, 1821.
[2] Hufeland and Himly's Journal der Pract. Heilkund., Nov., 1811, § 55.

and the observation of every one, whether of the medical profession or not, must have made him acquainted with those peculiarities that render a particular article of diet, which is innoxious, and even agreeable and wholesome to the generality of individuals, productive, in some, of the most unpleasant effects. Haller knew a person who was always violently purged by the syrup of roses. A friend of the author is purged by opium, which has an opposite effect on the generality of persons. Dr. Paris[1] says he knew two cases, in which the odour of ipecacuanha always produced most distressing dyspnœa: the author knew a young apothecary, who could never powder this drug without the supervention of the most violent catarrh; and Dr. Felix Robertson, of Tennessee,[2] has described his own case, in which violent asthma, attended with the most distressing dyspnœa and oppression at the pericardium, was induced by breathing the dust of ipecacuanha. Wine of ipecacuanha, taken as an emetic, occasioned, from the moment he swallowed it, "in the throat and stomach a sensation totally indescribable, but as intolerable to be borne (if life could have been sustained under it)" as if he had taken a drink of melted lead. The distress gradually subsided into one of his worst attacks of asthma. Yet, what is singular, until the time it first produced these effects, Dr. Robertson had been able to handle ipecacuanha with freedom and impunity. A friend of Tissot could not take sugar without its exciting violent vomiting. Urticaria or nettle-rash is very frequently occasioned, in particular constitutions, by eating shell-fish. The same effect is produced on two female friends of the author by eating strawberries; and similar cases are given by Roose. M. Chevalier relates the case of a lady, who could not take powdered rhubarb without an erysipelatous efflorescence showing itself, almost immediately, on the skin; yet she could take it in the form of infusion with perfect impunity.

The above idiosyncrasies apply, however, only to the digestive function. We find equal anomalies in the circulation. In some, the pulse is remarkably quick, upwards of one hundred in the minute; in others, it is under thirty. That of Napoleon is said to have beaten only forty-four times in a minute.[3] It may also be unequal, and intermittent, and yet the individual be in a state of health.

The senses offer some of the most striking cases of this kind of peculiarity. Many strong individuals cannot bear the smell of the apple, cherry, strawberry, musk, or peppermint. Pope Pius VII. had such an antipathy to musk, that, on the occasion of a presentation, an individual of the company having been scented with it, his holiness was obliged to dismiss the party almost immediately.[4] The late Lord Selkirk told Sir George Lefevre, that one of the most robust and indefatigable of the Northwest Company's agents could not sit in the room, if salmon were on table. He had been known to faint under such circumstances.[5]

[1] Pharmacologia, 4th Amer. edit. by J. B. Beck, p. 189, New York, 1831.
[2] Western Journ. of Med. and Surg., Aug., 1843.
[3] See some cases of unusual slowness of pulse, by Mr. H. Mayo, in Lond. Medical Gazette, May 5, 1838, p. 232; and in Amer. Med. Intel., July 2, 1838, p. 103. In one case of fatal disease the pulse beat only nine in the minute!
[4] Matthew's Diary of an Invalid.
[5] An Apology for the Nerves, by Sir George Lefevre, M.D., p. 101, Lond., 1844.

The idiosyncrasies of taste are also numerous; and some instances of singular depravation of the sense have been described under the Sense of Taste. M. Dejean gives the case of an individual of distinguished rank, who was fond of eating excrement. Certain animals, again, as the turkey, have an antipathy to the colour of red; and Von Büchner and Tissot cite the case of a boy who was subject to epileptic fits whenever he saw anything of a red colour. Occasionally, we meet with similar idiosyncrasies of audition. Sauvages relates the case of a young man labouring under intense headache and fever, which could not be assuaged by any other means than the sound of a drum. The noise of water issuing from a pipe threw M. Bayle into convulsions. The author has a singular peculiarity of the kind, derived from accidental association in early life. If a piece of thin biscuit be broken in his presence,—nay, the idea alone is sufficient,—the muscles that raise the left angle of the mouth are contracted; and this irresistibly. Nor is the sense of tact free from idiosyncrasies. Wagner cites the case of a person, who felt a sensation of cold along the back, whenever he touched the down of a peach with the point of his finger; or when the down came in contact with any part of his skin. He was remarkably fond of the fruit, yet was unable to indulge his appetite unless a second person previously removed the skin. Prochaska relates the case of a person, who was affected with nausea whenever he touched this fruit.

It is, of course, all important that the practitioner should be acquainted with these idiosyncrasies; and so far the notion of "knowing the constitution,"—which is apt to be used to the prejudice of the young practitioner, or of any except the accustomed medical attendant,—has some reason in it. It is the duty, however, of the patient to put the physician in the possession of the fact of such peculiarities, so that he may be enabled to guard against them, and not take that for morbid which is the effect of simple idiosyncrasy. This, however, is a topic which belongs rather to therapeutics.[1]

3. OF NATURAL AND ACQUIRED DIFFERENCES.

a. *Natural Differences.*

The temperaments, constitutions, and idiosyncrasies may, as we have seen, either be dependent upon original conformation, or they may be produced by external influences; hence, they have been divided into the *natural* and the *acquired*. Under the former head are included all those individual differences, derived from progenitors, which impress more or less resemblance to one or both parents. It has been properly observed, that the individuality of any human being that ever existed was absolutely dependent on the union of one particular man with one particular woman; and that if either the husband or the wife had been different, a different being would have been ushered into existence. For the production of Shakspeare, or Milton, or Newton, it was necessary that the father should marry the identical woman he did marry. If he had selected any other wife, there would have been no Shakspeare, no Milton, no Newton. Sons might have been born of other

[1] See the Author's General Therapeutics and Materia Medica, 4th edit., Philad., 1850.

women, but they would not have been the same, either in mental or physical qualities. All this, however, enters into the question of the influence of both parents on the fœtus in utero; which we have considered elsewhere.

a. *Peculiarities of the Female.*

Amongst the natural differences, those that relate to *sex* are the most striking. In a previous part of this volume, we have described the peculiarities of the sexual functions in both male and female, but other important differences have not been detailed. All the descriptions, when not otherwise specified, were presumed to apply to the adult male. At present, it will be only necessary to advert to the peculiarities of the female.

The stature of the female is somewhat less than that of the male, the difference being estimated at about a twelfth. The chief parts of the body have not the same mutual proportions. The head is smaller and rounder; the face shorter; the trunk longer, especially the lumbar portion, and the chest more convex. The lower extremities, especially the thighs, are shorter, so that the half of the body does not fall about the pubes, as in man, but higher. The neck is longer; the abdomen broader, larger, and more prominent; and the pelvis has a greater capacity, to adapt it for gestation and parturition. The long diameter of the brim is from side to side, whilst, in the male, it is from before to behind; the arch of the pubis is larger, and the tuberosities of the ischia are more widely separated, so that the outlet of the pelvis is larger than in the male; the hips are broader, and, consequently, the spaces between the heads of the thigh-bone greater; the knees are more turned in, and larger than in the male; the legs shorter, and the feet smaller. The shoulders are round; but the width across them, compared with that of the hips, is not so great as in man; the arms are shorter, fatter, and more rounded; the same is the case with the forearm; the hand is smaller, and softer, and the fingers are more delicate. The whole frame is more slender; the bones are smaller, their tissue is less compact, and the prominences and corresponding depressions are less marked; the subcutaneous areolar tissue is more abundant, and filled with a whiter and firmer fat; a similar adipose tissue fills up the intervals between the muscles, so that the whole surface is rounder, and more equable than that of the male; the skin is more delicate, whiter, better supplied with capillary vessels, and less covered with hair; the hair of the head, on the other hand, is longer, finer, and more flexible; the nails are softer and of a more red hue; the muscles of the face are less distinctly marked, so that the expression of the eye, and the emotions that occasion elevation or depression of the angles of the mouth, —laughing and weeping, for example,—are more strongly defined. On the whole, the general texture of the organs is looser and softer.

The above observations apply to what may be termed the *standard female*,—one whose natural formation has not been interfered with by employments, that are usually assigned to the other sex. It can be readily understood, that if the female has been accustomed to laborious exercise of her muscles, they may become more and more prominent,

the interstices between them more and more marked; the projections and depressions of the bones on which they move more distinct; the whole of the delicacy of structure may be lost; and the skeleton of one thus circumstanced, may be scarcely distinguishable from that of the inactive male, except in the proportions of the pelvis, in which the sexual differences are chiefly and characteristically situate.

Many of the functions of the female are no less distinctive than the structure. The senses, as a general rule, are more acute, whether from original delicacy of organization, or from habit, is not certain; probably both agencies are concerned. The intellectual and moral faculties are also widely different; and this, doubtless, from original conformation, although education may satisfactorily account for many of the differences observable between the sexes. Gall is one of the few anatomists who have attended to the comparative state of the cerebral system in the sexes; and the results of his investigations lead him to affirm, that there is a striking difference in the developement of different parts of the encephalon in the two, which he thinks may account for the difference observable in their mental and moral manifestations. In the male, the anterior and superior part of the encephalon is more developed; in the female, the posterior and inferior: the former of these he conceives to be the seat of the intellectual faculties; the latter of those feelings of love and affection that seem to preponderate in the character of the female. We have elsewhere said, that the views of Gall on this subject are not yet received as truths, and that we must wait until further experience and multitudinous observations shall have exhibited their accuracy, or want of foundation. Independently, however, of all considerations deduced from organization, observation shows, that the female exhibits intellectual and moral differences which are by no means equivocal. The softer feelings predominate in her, whilst the intellectual faculties have the preponderance in man. The evidences and character of the various shades of feeling and susceptibility, and the influence of education and circumstances on these developements, are interesting topics for the consideration of the moral philosopher, but admit of little elucidation from the labours of the physiologist. The only inference at which he can arrive is, that the causes of the diversity are laid in organization, and become unfolded and distinctive by education. The precise organization he is unable to depict, and the influence of circumstances on the mind it is scarcely his province to consider.

The function of muscular motion is, owing to more delicate organization, more feebly executed in the female. We have already remarked, that the bones are comparatively small, and the muscles more delicately formed. The energy of the nervous system is also less; so that all the elements for strong muscular contraction are by no means in the most favourable condition; and, accordingly, the power the female is capable of developing by muscular contraction is much less than that of the male. Her locomotion is somewhat peculiar,—the wide separation of the hip-joints, owing to the greater width of the pelvis, giving her a characteristic gait. The vocal organs exhibit differences, which account for the difference in the voice. The chest and lungs are of smaller dimensions; the trachea is of less diameter; the larynx smaller; the

glottis shorter and narrower; and the cavities, communicating with the nose, of smaller size. This arrangement causes the voice to be weaker, softer, and more acute. The muscles and ligaments of the glottis are apparently more supple, so as to admit of the production of a greater number of tones, and to favour singing. The phenomena of expression, as we have often remarked, keep pace with the condition of the intellectual and moral faculties, and with the susceptibility of the nervous system. As this last is generally great in the female, the language of the passions, especially of the softer kind, are more marked in her.

The functions of nutrition present, also, some peculiarities. With regard to digestion, less food is generally required; the stomach is less ample; the liver smaller; and frequently,—at least more frequently than in the male,—the dentes sapientiæ do not appear. The desire for food at the stated periods is not so powerful; and it is generally for light and agreeable articles of diet rather than for the very nutritious; but the appetite returns more frequently, and is more fastidious, owing to the greater sensibility of the digestive apparatus. This, however, is greatly an affair of habit, and we have more instances of prolonged abstinence in her than in the male. The circulation is generally more rapid, the pulse less full, but quicker. Of the secretions, that of the fat alone requires mention, which is usually more abundant, and the product firmer. The cutaneous transpiration is less active, and the humour has a more acidulous odour. The urine is said, by some, to be less abundant, and less charged with salts; whence, it is asserted, there is not so great a disposition to calculous affections. So far, however, as we have had an opportunity for judging, it is secreted in greater quantity; and this may partly account for its seeming to have a smaller quantity of salts in any given amount; but the truth is, the freedom of the female from calculous affections is greatly owing to the shortness and size of the urethra, which admits the calculus to be discharged with comparative facility; and it is a common observation, that where the males of a family, hereditarily predisposed to gout, owing to their greater exposure to the exciting causes, become affected with that disease, the females may be subject to calculous disorders,—the two affections appearing to be, in some respects, congenerous. For the reasons already mentioned, stone rarely forms in the bladder of the female, and the operation of lithotomy is scarcely ever necessary. The desire to evacuate the contents of the bladder occurs more frequently in her,—probably, in part, owing to habit; and, in part, to the greater mobility of the nervous system.

In addition to these differences as regards the secretions, the female has one peculiar to herself,—menstruation,—a function which has already engaged attention. In the progress of life, too, the glandular system undergoes evolutions which render it especially liable to disease. About the period of the cessation of the menses,—sooner or later,—the mammæ frequently take upon themselves a diseased action, and become scirrhous and cancerous so as to require the organs to be extirpated.

In the treatment of disease, these sexual peculiarities have to be borne in mind. Owing to the greater mobility of the nervous system

in the female, she usually requires a much smaller dose of any active medicine than the male; and during the period when the sexual functions are particularly modified, as during menstruation, gestation, and the child-bed state, she becomes liable to various affections, some of which have been referred to elsewhere; others belong more appropriately to works on pathology, therapeutics, or obstetrics.

b. *Acquired Differences.*

The acquired differences, observed amongst individuals, are extremely numerous. The effect of climate on the physical and mental characteristics is strikingly exhibited. The temperate zone appears to be best adapted for the full developement of man, and it is there, that the greatest ornaments of mankind have flourished, and that science and art have bloomed in exuberance; whilst in the hot, enervating regions of the torrid zone, the physical and moral energies are prostrated; and the European or Anglo-American, who has entered them full of life and spirits, has left them after a few years' sojourn, listless and shorn of his proudest characteristics. Nor is the hyperborean region more favourable to mental and corporeal developement;—the sensibility being blunted by the rigours of the climate. The effect of locality is, perhaps, most signally exemplified in the *Crétin* and the *Goîtreux*, of the Valais, and of the countries at the base of lofty mountains in every part of the globe; as well as in the inhabitants of our low countries, who are constantly exposed to malarious exhalations, and bear the sallow imprint on the countenance.

Not less effective in modifying the character of individuals is the influence of way of life, education, profession, government, &c. The difference between the cultivated and the uncultivated; between the humble mechanic, who works at the anvil or the lathe, and him whose avocation, like that of the lawyer and physician, consists in a perpetual exercise of the organ of intellect; and between the debased subject of a tyrannical government, and the independent citizen of a free state,—

> "Lord of the lion heart and eagle eye,"

is signal and impressive.

1. *Habit.*

To acquired differences from extraneous or intrinsic causes we must refer *habit*, which has been defined,—an acquired disposition in the living body, that has become permanent, and as imperious as any of the primitive dispositions. It is a peculiar state or disposition of the mind, induced by the frequent repetition of the same act. Custom and habit are frequently used synonymously; but they are distinct. Custom is the frequent repetition of the same act; habit is the effect of such repetition. By custom we dine at the same hour every day: the artificial appetite induced is the effect of habit.

The functions of the frame are variously modified by this disposition,—being, at times, greatly developed in energy and rapidity; at others, largely diminished. If a function be over and over again exerted to the utmost extent of which it is capable, both as regards

energy and activity, it becomes more and more easy of execution; the organ is daily better adapted for its production, and is so habituated to it, that it becomes a real want—a *second nature*. It is in this way, that we accustom the organs of speech, locomotion, &c., to the exercise of their functions, until, ultimately, the most varied combinations of muscular movements of the tongue and limbs can be executed with surprising facility. If, on the contrary, the organs of any function possess unusual aptitude for accomplishing it, and we accustom ourselves to a minor degree of the same, we ultimately lose a part of the aptitude, and the organs become less inclined, and less adapted to produce it. By custom we may habituate ourselves to receive an unusually small quantity of nutriment into the stomach, so that at length it may become impracticable to digest more.

A similar effect occurs as regards the quantity of the special irritant, which we allow to impinge on any of the organs of sense. If we accustom them to be feebly impressed, yet sufficiently so for the performance of their functions, they become incapable of supporting a greater quantity of the special irritant without indicating suffering. The miner can see into the farthest depths of his excavations, when, to the eye of one, who has descended from the bright light of day, all seems enveloped in obscurity. In this case, the sensibility of the organ of sight is developed to such an extent, that if the individual be brought into even a feeble light, the impression is extremely painful. The nyctalope is precisely so situate. His nerves of sight are so irritable, that, although he can see well in the night, he is incapable of accurate discrimination by day. On the other hand, exposure to intense light renders the sensibility of the visual nerves so obtuse, that objects are not so readily perceived in obscurity. The hemeralope, who sees in the day and not in the night, and who is consequently the antitheton of the nyctalope, has the nervous system of vision unusually dull, and incapable of excitement by feeble impressions.

It may be laid down as a general principle, that if we gradually augment the stimulus applied to any organ of sense, it becomes less susceptible of appreciating minor degrees of the same irritant; so that, in this way, an augmented dose is progressively required to produce the same effect. This is daily exemplified by the use of tobacco,—either in the form of chewing, smoking, or snuffing, which becomes a confirmed habit, and can only be abandoned—without doing great violence to the feelings—by attention to the principle deduced from practice,—that by gradually following the opposite course to the one adopted in acquiring the habit—that is, by accustoming the nerve of sense to a progressive diminution in the dose of the stimulus—an opposite habit may be formed, and the evil, in this manner, be removed.

When, by habit, we acquire extreme facility in executing any function, it may be accomplished apparently without the direct agency of volition. This is peculiarly applicable to the voluntary motions. We have elsewhere shown, that, in this case, habit only communicates the facility, and that there is no natural sequence of motions, and, consequently, no reason,—as in executing a rapid musical movement,—why one movement of the fingers should follow rather than another,

unless volition were the guiding power. A sensation, however, which at first excites a perceptible exertion of volition, will, in time, produce it and the correspondent action, without our being sensible of its interference; and so rapid is this process, that we seem to will two ends or objects at the same time, although they are evidently, when examined, distinct operations. The musician is not sensible of his willing any one motion; yet with the most exquisite nicety he touches a particular part of the string of the violin, and executes a variety of the nicest and most complicated movements with the most delicate precision.

It is a common remark, that "habit blunts the feeling but improves the judgment." To a certain extent this is true; but feeling is not blunted unless the stimulant, which acts upon the organ of sense, is too powerful, and too frequently repeated. When moderately exercised, the effect of education, in perfecting all the senses, is strongly shown. Sensations, often repeated, cease to be noticed, not because they are not felt, but because they are not heeded; but if the attention be directed to the sensation, custom adds to the power of discrimination. Hence the sailor is able to detect the first appearance of a sail in the distant horizon, when it cannot be perceived by the landsman; and a similar kind of discrimination is attained by the due exercise of other senses. The greater power of discrimination is doubtless owing to improvement in the cerebral or percipient part of the visual apparatus; but we have no evidence, that the latter has its action necessarily blunted.

It has been presumed by some physiologists and metaphysicians, that the will, by custom and exercise, may acquire a power over certain functions of the body which were not originally subject to it; nay, some speculatists have gone farther, and affirmed, that all the involuntary functions were originally voluntary, and have become involuntary by habit. Stahl and the other animists, who regarded the soul as the formative and organizing agent in animals, asserted, that it excites the movements of the heart, and of the respiratory, digestive, and other nutritive organs, by habits so protracted and inveterate, and so naturalized within us, that these functions can be effected without the aid of the will, and without the slightest attention being paid to them. Respiration, according to them, is originally voluntary; but, by habit, has become spontaneous; so that there is no farther occasion to invoke volition. Respiration goes on night and day, when we are asleep as well as awake; and they regard, as a proof that the action was originally dependent upon free will, that we are still able to accelerate or retard it at pleasure. They cite, moreover, the case of Colonel Townshend, related in another part of this work, (p. 145 of this volume,) to show, that the action of the heart is capable of being influenced by the will; as well as the fact that it is accelerated or retarded under the different passions.

MM. Condillac, Dutrochet, and De Lamarck,[1] again, fantastically assert, that the different instincts, observed to prevail so powerfully in animals, are mere products of an acquired power, transmitted through successive generations. The views of the last distinguished naturalist

[1] Philosophie Zoologique, tom. i. p. 218; and tom. ii. p. 451, edit. 1830.

regarding the effect of habit on organization, which he considers to tend to greater and greater complication, are singular and fantastic. The organs of an animal have not, he maintains, given rise to its habits: on the contrary, its habits, mode of life, and those of its ancestors have, in the course of time, determined the shape of its body, the number and condition of its organs, and the faculties it enjoys. Thus, the otter, the beaver, the waterfowl, the turtle, and the frog were not made web-footed that they might swim; but their wants having attracted them to the water in search of prey, they stretched out their toes to strike the water, and move rapidly along its surface. By the repeated stretching of the toes the skin that united them at the base acquired a habit of extension; until, in the course of time, they became completely web-footed. The camelopard, again, was not gifted with a long flexible neck, because it was destined to live in the interior of Africa, where the soil is arid and devoid of herbage; but, being reduced by the nature of the country to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its fore-legs became longer than the hinder, and its neck so elongated that it could raise its head to the height of twenty feet above the ground!

The objections to all these views are,—that the functions in question are as well performed during the first day of existence as at an after period, and are apparently as free from the exercise of volition. The heart beats through fœtal existence for months before the new being is ushered into the world; and when, if volition is exerted at all, it can only be so obscurely. The case of Colonel Townshend is strange—passing strange—but it is almost unique; and the power of suspending the heart's action was possessed by him a short time only prior to dissolution. All the functions in question must, indeed, be esteemed *natural*, and instinctive, inseparably allied to organization; and hence differing from the results of habit, which are always *acquired*.

The opinion of Bichat, on the other hand, was, that habit influences only the animal functions, and has no bearing on the organic or nutritive. But this is liable to objection. We have seen, under Digestion, that if a bird, essentially carnivorous in its nature, be restricted to vegetable food, the whole digestive apparatus is modified, and it becomes habituated to the new diet. We know, also, that where drains are established in any part of the body, they become, in time, so much a part of the normal condition, that they can only be checked with safety by degrees.[1]

In the administration of medicines, habit has always to be attended to. The continued use of a medicine generally diminishes its power:—hence the second dose of a cathartic ought to be larger than the first, if administered within a few days. Certain cathartics are found, however, to be exceptions to this. Cheltenham water and the different saline cathartics are so. The constitution, so far from becoming reconciled to lead by habit, is rendered more and more sensible to its irritation. Emetics, too, frequently act more powerfully by repetition. Dr. Cullen asserts, that he knew a person so accustomed to excite vomiting

[1] Adelon, in Dict. de Méd., x. 498; and Physiologie de l'Homme, edit. cit., iv. 525.

on himself, that the one-twentieth part of a grain of tartrate of antimony and potassa was sufficient to produce a convulsive action of the parts concerned in vomiting. As a general rule, however, medicines lose their effect by habit, and this is particularly the case with tonics; but if another tonic be substituted for a day or two, and the former be resumed, it will produce all its previous effects.

2. *Association.*

Association, employed abstractedly, is a principle of the animal economy nearly allied to habit. When two or more impressions have been made upon the nervous system, and repeated for a certain number of times, they may become associated; and if one of them only be made it will call up the idea of the other. It is a principle, which is largely invoked by the metaphysician, and by which he explains many interesting phenomena of the human mind, especially those connected with our ideas of beauty, or the contrary; our likes and dislikes, and our sense of moral propriety. Dr. Darwin[1] employed it to explain many complicated functions of the economy; and laid it down as a law, that all animal motions, which have occurred at the same time or in immediate succession, become so associated, that when one of them is reproduced, the other has a tendency to accompany or succeed it. The principle has, doubtless, great agency in the production of many of the physical, as well as psychical, phenomena; but its influence has been overrated; and many of the consecutive and simultaneous actions, to which we have referred under the head of Correlation of Functions, take place apparently as well the first time they are exerted as subsequently. Sucking and deglutition are good cases of the kind. Soon after birth, the muscles of the lips, cheeks, and tongue are contracted to embrace the nipple, and to diminish the pressure in the interior of the mouth; and, as soon as the milk has flowed to the necessary extent into the mouth, certain voluntary muscles are contracted. These propel the milk into the pharynx, where its farther progress is effected by muscles, *associated* or connected functionally, but not in the sense we are now employing the epithet; for here one action could not suggest another, according to the definition we have given of *association*, which requires that the acts should have been executed previously. Many of the cases, in fact, ascribed by Messrs. Darwin and Hartley[2] to the agency of this principle, are instinctive actions, in which a correlation —as in the case of deglutition—exists, but without our being able to explain the nature of such correlation, any more than we can explain other complicated actions and connections of the nervous system, of which this is doubtless one. Some of the most obstinate diseases are kept up by habit, or by accustomed associated motions; and, frequently, the disease seems to continue from this cause alone. Whenever intermittent fever, epilepsy, asthma, chorea, &c., have been long established, the difficulty of removing the influence of habit, or the tendency to recurrence, is extreme. In such cases, the principle of revulsion can be invoked with much advantage by the therapeutist.

[1] Zoonomia, i. 49, Lond., 1794.

[2] On Man, i. 102, Lond., 1791.

3. *Imitation.*

The principle of imitation falls appropriately under this section. It may be defined,—that consent of parts, depending on similar organization, which, under the influence of the brain, enables them to execute acts similar to those executed by the same parts in another individual. Imitation, consequently, requires the action of the brain; and differs from those actions that are natural or instinctive to organs. For example, speech requires the action of imitation; whilst the ordinary voice or cry is effected by the new-born, and by the idiot, who are incapable of all observation, and consequently of imitation. The mode in which speech is acquired offers us one of the best examples of this imitative principle—if we may so term it. At a very early period, the child hears the sounds addressed to it, and soon attaches ideas to them. It discovers, moreover, that it is capable of producing similar sounds with its own larynx, and that these sounds are understood, and inservient to the gratification of its wants; and, in this way, speech, as we have elsewhere seen, is acquired. The difficulty is to understand in what manner this singular consent is produced. Sir Gilbert Blane has properly remarked, that the imitation of gestures is, at first sight, less unaccountable than that of sounds; as they are performed by organs that are objects of sight, and would seem therefore to be more readily transferable to corresponding organs of another person; but he probably errs, when, farther on, he remarks, that when children begin to articulate, they first attempt those letters, in the pronunciation of which the motions of the organs are the objects of sight; such as the *p* and *b*, among consonants, and the broad *a*, among the vowels, "giving occasion to a well-known etymology, from the infantile syllables, expressive of father and mother in all languages." We do not think, that this explanation is happy; and have elsewhere attempted to show, that the combination of letters, and the words referred to, are first enunciated, because they are the easiest of all combinations; and that the expressions *mama*, *papa*, &c., are employed long before the child has acquired the power of imitation, and prior to its attaching the meaning to the words which it is subsequently taught to adopt. It is certainly singular how the child can learn to imitate sounds, where the action of the organs concerned is completely concealed from view. The only possible way of explaining it is to presume, that it makes repeated attempts with its vocal apparatus to produce the same sound it hears; and that it recollects the sensation produced by the contraction of the muscles when it succeeds; so as to enable it to repeat the muscular action and the sensation, at pleasure. This is, however, a case in which volition is actively exerted. We have others, where the action occurs in spite of the individual, as in yawning. We see it in a second person, and, notwithstanding all our attempts to the contrary, the respiratory organs are excited through the brain, and we accomplish the same act. Nay, even thinking of the action will be sufficient to arouse it. Of a like nature to this is the sympathetic contraction of the uterus, which comes on, where a pregnant female is in the lying-in chamber during the accouchement of another, and to which we have referred under the

head of Sympathy. Many morbid phenomena are excited in a similar manner:—of these, squinting and stammering are familiar examples. Of 321 cases of squinting, of which the exciting causes were investigated, 61 were found to be produced by imitation.[1]

4. OF THE VARIETIES OF MANKIND.

To determine the number of varieties, into which the great human family may be divided, is a subject considered to belong so completely to the naturalist, that we shall pass it over with a brief inquiry.

If we cast our eye over the globe, although we may find, that mankind agree in their general form and organization, there are many points in which they differ materially from each other. "With those forms, proportions, and colours, which we consider so beautiful in the fine figures of Greece,"—to use the language of Mr. Lawrence,[2]—"contrast the woolly hair, flat nose, thick lips, the retreating forehead, advancing jaws, and black skin of the negro; or the broad, square face; narrow oblique eyes; beardless chin; coarse, straight hair, and olive colour of the Calmuck. Compare the ruddy and sanguine European with the jet black African, the red man of America, the yellow Mongolian, or the brown South-Sea Islander; the gigantic Patagonian to the dwarfish Laplander; the highly civilized nations of Europe, so conspicuous in arts, science, literature, in all that can strengthen and adorn society, or exalt and dignify human nature, to a troop of naked, shivering, and starved New Hollanders, a horde of filthy Hottentots, or the whole of the more or less barbarous tribes, that cover nearly the entire continent of Africa;—and although we must refer them all to the same species, they differ so remarkably from each other as to admit of being classed in a certain number of great varieties; but with regard to the precise number, naturalists have differed materially."

Under the idea, that mankind are descended from one original pair, whatever changes have been impressed upon mankind can, of course, apply only to the descendants of Noah. The broad distinctions we now meet with could scarcely have existed in his immediate family, saved with him at the time of the deluge. They must necessarily have been of the same race. None of our investigations on this subject can, consequently, be carried back into antediluvian periods. Hence, the region, on which the ark rested, must be looked upon as the cradle of mankind. The question of the original residence of man has frequently engaged the attention of the philologist. It is one, which could be answered positively by the historian only, but unfortunately, the evidence we possess of an historical character is scanty in the extreme; and the few remarks in the sacred volume are insufficient to lead us to any definite conclusion. As far back as the date of the most remote of our historical records,—which extend to about two thousand years prior to the Christian era,—we find the whole of Asia and a part of Africa,—probably a large part,—peopled by different nations, of various manners, religion, and language; carrying on extensive wars with

[1] Med. Examiner, July 10, 1841, p. 439.
[2] Lectures on Comparative Anatomy, Physiology, Zoology, and the Natural History of Man, 9th edit., p. 165, London, 1844.

each other; with here and there, civilized states, possessing important inventions of all kinds, which must have required a length of time for discovery, improvement, and diffusion. After the subsidence of the deluge, the waters would first recede from the tops of the highest mountains, which would thus be the earliest habitable; and, in such a situation, the family of Noah—it has been conceived—increased, and thence spread abroad on the gradual recession of the waters. The earliest habitable spot was perhaps the elevated region of middle Asia, not the summits, which would be unsuitable, in every respect, for human existence; but some of the lofty plains, such as that of which the well-known desert Kobi or Schamo forms the highest point, and whence Asia sinks gradually towards the four quarters, and the great mountain chains proceed that intersect Asia in every direction. This has been suggested by Herder[1] and Adelung[2] as the cradle of the human race. In the declivities of this elevated region, and of its mountain chains, all the great rivers arise that flow on every side through that division of the globe. After the deluge, it would therefore soon become dry and project, like an extensive island, above the flood. The cold and barren elevation of Kobi would not itself have been well adapted for the continued residence of our second parents, but immediately on its southern side lies the remarkable country of Thibet, separated by lofty ridges from the rest of the world, and containing within itself every variety of climate. Although on the snow-capped summits the severest cold perpetually prevails, summer eternally reigns in the valleys and well-watered plains. The rice, too, the vine, pulse, and a variety of other productions of the vegetable kingdom, which man employs for his nutrition, are indigenous there; and those animals are found in a wild state which man has domesticated and taken along with him over the earth;—the ox, horse, ass, sheep, goat, camel, swine, dog, cat, and even the reindeer,—his only friend and companion in the icy deserts of polar regions. Zimmermann,[3] indeed, asserts, that every one of the domesticated animals is originally from Asia. Close to Thibet, and immediately on the declivity of this great central elevation, is the charming region of Kaschemire, the lofty site of which tempers the southern heat into a protracted spring.

The probabilities in favour of the cradle of mankind having been situate to the south of the elevated region of middle Asia are considered to be strengthened by the circumstance of the nations in the vicinity possessing a rude, meagre, and imperfect language, such as might be imagined to have existed in the infancy of the human intellect and of the world. Not less than two hundred millions of people are found there, whose language appears to be nearly as simple as it must have been soon after its formation. Kaschemire, by reason of the incessant changes it has experienced in ancient and modern times, has kept pace with the rest of the world in the improvement of its language; but not so, apparently, Thibet—its neighbour—and China, and

[1] Ideen zur Philosophie der Geschichte der Menschheit, Riga und Leipz., 1785–1792.

[2] Mithridates oder Allgemeine Sprachenkunde, Berlin, 1806–1817, Erster Theil, Einleitung.

[3] Geograph. Geschichte der Menschen, u. s. w., Leipz., 1778.

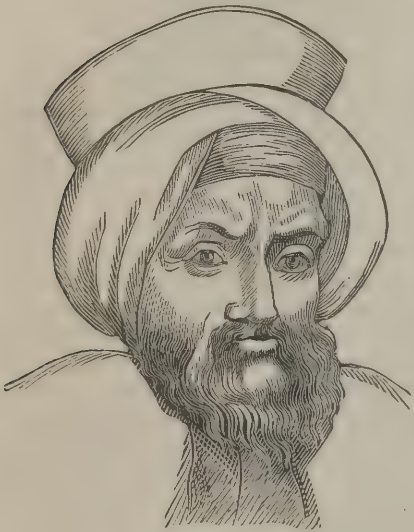
the kingdoms of Ava, Pegu, Siam, Tunkin, and Cochinchina. All these extensive countries, and these alone in the known world, according to Adelung, betray the imperfection of a newly-formed or primitive language. As the earliest attempt of the child is a stammering of monosyllabic tones, so,—says that eminent philologist,—must have been that of the original child of nature; and, accordingly, the Thibetans, the Chinese, and their two neighbours to the south continue to stammer monosyllabically, as they must have done thousands of years ago, in the infancy of their race. "No separation of ideas into certain classes, whence arose the parts of speech in cultivated languages. The same sound, which denotes *joyful*, signifies *joy* and to *gladden*, and this in every person, number, and tense. No art, connexion, or subordinate ideas are united to the rude, monosyllabic root, thereby communicating richness, clearness, and euphony to their meagre tongue. The rude, monosyllabic, radical ideas are placed, perhaps broken, and detached from each other, the hearer being left to supply the intermediate ideas. As the monosyllable admits of no inflection, the speaker either makes no distinction between cases and numbers, or he seeks for aid, in cases of great necessity, in circumlocution. The plural he forms, like the child, either by repetition,—*tree*, *tree*,—or by the addition of the words *much* or *more*, as *tree much*, *tree more*. *I much*, or *I more* is the same to him as *we*." From these and other circumstances, Adelung infers, that monosyllabic languages are primitive and the honourable ancestors of all others; but the argument is more plausible perhaps than sound. It has been correctly remarked by the author's distinguished friend, the late Mr. Duponceau, that, in all languages, there is a strong tendency to preserve their original structure, and from the most remote period, to which the memory of man can reach, a monosyllabic language has never been known to become polysyllabic, or conversely. Adelung farther infers, that the immediate descendants of Noah originally occupied the favoured region which he has described, and as population increased spread into the neighbouring districts, selecting, by preference, the near and charming countries of the south, east, and west. Hence we find, in those immediately bordering on Thibet, the earliest formed states, and the oldest civilization. History refers us to the East for the primordial germs of most of our ideas, arts, and sciences, whence they subsequently spread to the countries farther to the West, to Media, Persia, and western Asia.

1. *Division of the Races.*

It is probable, that from western Asia, the sons of Noah,—Shem, Ham, and Japheth,—branched off in various directions, so as to constitute the three distinct stocks that divided the old world from time immemorial. These three are—1, the *White*, *Caucasian*, *Arabico-European*, or *European;* 2, the *Olive*, *Mongolian*, *Chinese*, *Kalmuck*, or *Asiatic;* and 3, the *Negro*, *Ethiopian*, *African*, *Hottentot*, &c., each of which has its own principal habitat;—the white being found chiefly in Europe and Asia Minor, Arabia, Persia, and India as far as the Ganges, and in North Africa; the Mongol occupying the rest of Asia, and having its focus on the plateaux of Great Tartary and Thibet;

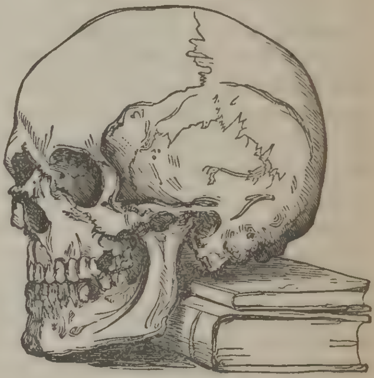
and the negro race covering almost the whole of Africa, and some of the Isles of New Guinea, the country of the Papuas, &c. The white or Caucasian variety are supposed to be the descendants of Japheth ("*audax Japeti genus*," Horace); the Asiatic the descendants of Shem; whilst Ham is regarded as the parent of the African. These

Fig. 466.



Caucasian Variety. (Blumenbach.)

Fig. 467.



Oval Skull of a European. (Prichard.)

three races,—the *Caucasian*, *Negro*, and *Mongolian*,—are alone admitted by Cuvier.[1] Blumenbach,[2] whose classification will serve our purpose as well as any of the others to which reference will be made presently, admits five,—the *Caucasian*, *Ethiopian*, *Mongolian*, *American*, and *Malay*.

a. *Caucasian Race.*

The Caucasian race is chiefly distinguished by the elegant form of the head, which approximates a perfect oval. It is also remarkable for variations in the shades of the complexion and colour of the hair. From this variety, the most civilized nations have sprung. The name *Caucasian* was given to it from the group of mountains between the Caspian and the Black Sea,—tradition seeming to refer the origin of this race to that part of Asia. Even at the present day, the peculiar characteristics of the race are found in the highest perfection amongst the people who dwell in the vicinity of Mount Caucasus,—the Georgians and Circassians,—who are esteemed the handsomest people of the earth. The above figure, 466, is given by Blumenbach as a specimen of the Caucasian race, near the original residence whence the

[1] Règne Animal.

[2] Handbuch der Naturgeschichte, § 52, Götting., 1791; and De Generis Humani Varietat. Nativ., Götting., 1777.

epithet is derived. It represents Jusuf Aguiah Efendi, formerly ambassador from the Porte to London.

The Caucasian race has been subdivided into several great nations or families:—1. The *Arabs*, comprising the Arabs of the desert, or Bedouins, the Hebrews, Druses, and other inhabitants of Libanus, the Syrians, Chaldæans, Egyptians, Phœnicians, Abyssinians, Moors, &c. 2. The *Hindoos* on the European side of the Ganges;—as the inhabitants of Bengal, of the coasts of Coromandel and Malabar, the ancient Persians, &c. 3. The *Scythians* and *European Tartars*, comprising also the Circassians, Georgians, &c. 4. The *Kelts* or *Celts*, whose precise origin is unknown, but presumed to be Indian. The descendants of this race are the Gauls, Welsh, Rhætians, &c. &c.; and lastly, the *Goths*, the ancestors of the Germans, Dutch, Swedes, Danes, &c. Both the ancient Kelts and Goths would seem to have been xanthous or fair haired races; although the former have often been described as dark haired; but this is by no means the case with their descendants.[1]

That the time of the first peopling of the European countries must have been very remote is exhibited by the fact, that at the dawn of history, the whole of Europe, from the Don to the mouth of the Tagus, was filled with nations of various physical characters and languages, bearing striking marks of intermixture and modification. At this period, there were, in Europe, at least six great nations. 1st. The *Iberians* with the *Cantabri*, in Spain, a part of Gaul, and on the coasts of the Mediterranean as far as Italy. 2dly. The *Kelts*, in Gaul, in the British Isles, between the Danube and the Alps, and in a part of Italy. 3dly. The *Germani* or *Goths*, between the Rhine, Danube, and Vistula. 4thly. The *Thracians*, with the *Illyrians*, in the southeast of Europe, and in western Asia. 5thly. The *Sclavi* in the north: and 6thly. The *Fins* in the northeast. It is not improbable, that these different races migrated from Asia in the above order;—such at least is the theory of certain historians and philologers, and there is some reason for adopting it. They who migrated first would probably extend their wanderings until they were arrested by some invincible obstacle, or until the arrival of fresh tribes would drive them onwards farther and farther towards the west. In this way, they would ultimately reach the ocean, which would effectually arrest their farther progress, unless towards the south and north. The descendants of the ancient Iberians do now actually occupy the west of Spain,—the residence probably of their forefathers. Nearly about the same time, perhaps, as the Iberians undertook their migration, the Kelts, a populous tribe, migrated from some part of Asia, and occupied a considerable portion of middle Europe. To these succeeded the Goths, to the north, and the Thracians to the south; whilst the Sclavi, the last of the Asiatic emigrants, wandered still farther north. It is not easy to determine the precise link occupied by the Fins in this vast chain of nations. They were first known to history as a peculiar people in the north of Europe; but whence they proceeded, or whether they occupied their position to the north of the Germani from choice, or were urged onwards by their more powerful

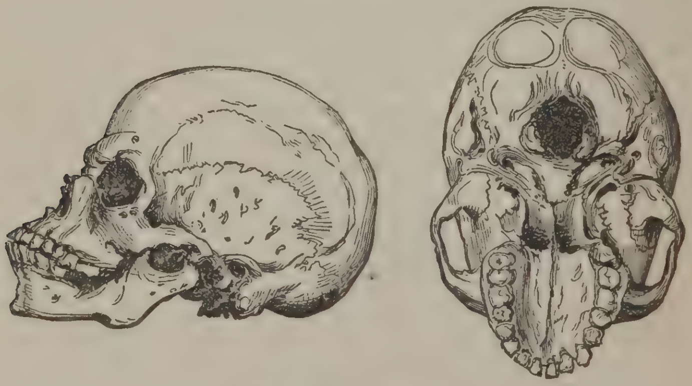
[1] Prichard, Natural History of Man, p. 195, Lond., 1843.

neighbours, we know not. So long as there was sufficient space for the nations to occupy, without disturbing the possessions of their neighbours, they probably kept themselves distinct; but as soon as the land was filled, a contest arose for the possession of more extensive or more eligible regions; wars were, consequently, undertaken, and the weaker gradually yielded their possessions, or their sovereignty, to the stronger. Hence, at the very dawn of history, numerous nations were met with, amalgamated both in blood and language;—for example, the Kelto-Iberians of Spain; the Belgæ or Kymbri of Gaul and Britain; the Latins, and other nations of Italy, and probably many, whose manners, characters, and language had become so melted into each other as to leave little or no trace of the original constituents. The Letti, Wallachians, Hungarians, and Albanians of eastern Europe, are supposed to afford examples of such amalgamation, whilst the mighty Sclavonic nation has swallowed up numbers of less powerful tribes, and annihilated even their names forever. This it is, which frequently embarrasses the philological historian; and prevents him, without other evidence, from deducing with accuracy the parent stocks, or the most important components in ethnical admixtures. Dr. Morton, in his splendid and valuable contribution to the Natural History of Man,[1] subdivides the Caucasian race into seven families:—the Caucasian, Germanic, Celtic, Arabian, Libyan, Nilotic, and Indostanic.

b. *Ethiopian Race.*

The *Negro*, *African*, *Ethiopian*, or *black man* of Gmelin, occupies a less extensive surface of the globe, embracing the country of Africa which extends from the southern side of Mount Atlas to the Cape of Good Hope. This race is of a less perfect organization than the last,

Fig. 468.



Negro Skull. (Prichard.)

and has some characteristics, which approximate it more to the monkey kind. The forehead is flattened and retiring; the skull smaller, and is

[1] Crania Americana, p. 5, Philad., 1839.

of less capacity than that of the European. On the other hand, the face, which contains the organs of sense, is more developed, and projects more like a snout. The head is in other words *prognathous* or has the jaws prolonged or extended forward. The lips are large; the cheek bones prominent; the temporal fossæ hollower; the muscles of mastication stronger; and the facial angle smaller;—the head of the negro, in this respect, holding a middle place between the Caucasian and orang-outang. The nose is expanded; the hair short and woolly, very black and frizzled. It has been considered by some to be wool, and not hair; and, therefore, a characteristic of the African races, and of some other dark-coloured tribes chiefly inhabiting tropical climates. A recent writer,[1] who embraces the former view, affirms, as the result of his microscopic observation, that the hair of the Choctaw and some other nations of American Indians is cylindrical: that of the white man oval; whilst "the wool of the negro is *eccentrically elliptical* or *flat*." But its woolly nature is not admitted by distinguished anthropological observers; as by Dr. Prichard;[2] and Dr. Carpenter[3] affirms, that "microscopic examination clearly demonstrates, that the hair of the negro has exactly the same structure with that of the European, and that it does not bear any resemblance to wool save in its crispness and tendency to curl." Dr. Neill[4] has recently drawn attention to the fact, that in the negro particularly, the condyloid processes of the occipital bone are divided by a transverse ridge or groove into two distinct articular surfaces, which are often in different planes; and farther, that the superior maxillary bone has a distinguishing mark. In the Caucasian head, there is a sharp ridge or crest continuous with the anterior edge of the nasal process, and reaching to the anterior nasal spine; which is wanting in the Ethiopian head,—the surface in it being flat and the orifice of the nose resembling that of the "monkey and other inferior mammalia." In the superior maxillary bone of the fœtus, the crest is equally wanting and the surface flat; so that "here again"—Dr. Neill remarks—"we see, that the adult African head permanently retains a form characteristic of the fœtal head, and that this form belongs to many inferior animals." The Ethiopian has, moreover, a less developement of the fingers, and therefore a greater length of web. The skin is black, but this colour is not characteristic of the race, for the Hottentots and Caffres are yellow.

The next figure is the head of J. J. E. Capitein, selected by Blumenbach as the representative of his race. He was an intelligent negro, and published several sermons and other works in Latin and Dutch. His portrait was taken by Van Dyk. This case of great intelligence in the negro is uncommon; but it exhibits what may be expected from him under favouring circumstances. In almost all situations in which he is found, it is in a state of slavery and degradation, and no inference can be deduced regarding his original Grund-

[1] P. A. Browne, The Classification of Mankind by the Hair and Wool of their Heads, p. 4, Philadelphia, 1850.

[2] Op. cit., p. 103.

[3] Principles of Human Physiology, 4th Amer. edit., p. 79, Philad., 1850.

[4] Amer. Journal of the Medical Sciences, Jan., 1850, p. 78.

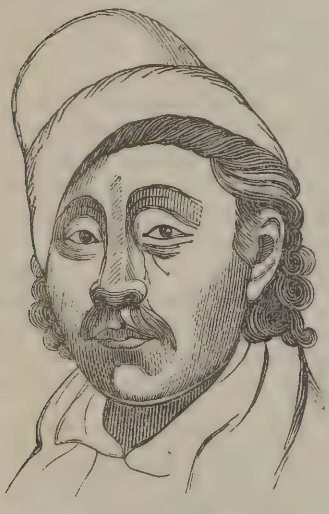
Fig. 469.

Ethiopian Variety. (Blumenbach.)

kraft—as the Germans call it—or intellectual capability. Hayti has afforded numerous examples of the sound judgment, and even distinguished ability with which her sable inhabitants are capable of conducting not only the municipal, but foreign concerns of a considerable community. It must be admitted, however, that from organization, this race would seem to be, *cæteris paribus*, less fitted for intellectual distinction than the Caucasian,[1] and singular differences have been observed between the two, when exposed to similar mental and physical influences.[2] The Ethiopian race is subdivided by Dr. Morton[3] into six families:—the Negro, Caffrarian, Hottentot, Oceanic Negro, Australian, and Alforian.[4]

c. *Mongolian Race.*

Fig. 470.



Mongolian Variety. (Blumenbach.)

The *Mongolian*, *Asiatic*, *Kalmuck*, or *Chinese* race, *brown man* of Gmelin, is recognised by prominent wide cheek bones; flat, square visage; small, oblique eyes; straight black hair; scanty beard, and olive complexion. The marginal head is from Blumenbach. It is that of Feodor Ivanowitsch, a Kalmuck, given by the Empress of Russia to the hereditary Princess of Baden. He was educated at Carlsruhe, and was a most distinguished painter at Rome. The portrait was sketched by Feodor himself.

The Mongols are spread over the central and eastern parts of Asia, with the exception of the peninsula of Malacca. They likewise stretch along the whole of the Arctic regions, from Russia and Lapland to Greenland, and the Northern parts of the American continent, as far

[1] See vol. i. p. 330.

[2] See abstract of a memoir by Dr. B. H. Coates, "On the effects of secluded and gloomy imprisonment on individuals of the African variety of mankind in the production of disease," in Proceedings of the Amer. Philosoph. Soc., vol. iii. p. 143, Philad., 1843; also a paper by M. Boudin on the Comparative Pathology of the different races of Men, in Annales d'Hygiène, xlii. 38–80, cited in British and Foreign Medico-Chirurgical Review, Oct. 1849, p. 551; and the Report of a Committee, of which Dr. Isaac Parrish was Chairman, on the effects of confinement in prisons and penitentiaries, &c. &c., on the health of their inmates, in Transactions of the American Medical Association, vol. 2, Philad., 1849.

[3] Op. citat., p. 7.

[4] The Alfores or Horaforas are considered aboriginal in many islands of the Indian Archipelago. They are most numerous in New Guinea, the Moluccas, and Magindano: in Celebes,

as Behring's Straits,—the Laplanders and Esquimaux being evidently of the same race as the Koriaks, Kamtschadales, Japanese, &c., of the Asiatic continent. Dr. Morton includes in this race five families:—the Mongol-Tartar; Turkish; Chinese; Indo-Chinese, and Polar.

d. *American Race.*

The *American race*, *red man* of Gmelin, or more properly *brown man*, differs greatly in stature, colour, and physiognomy in various parts of the continent; but his medium height corresponds with that of

Fig. 471.

American Variety. (Godman.)

the European. His colour is from a cinnamon-brown to a deep copper. The hair is almost always black, straight, and stiff. The features are large and strongly marked, except the eyes, which are commonly deep-seated, or sunk in large sockets. The forehead is generally low, somewhat compressed at the sides, and slightly retreating. Facial angle about 80°. Nose generally considerably raised from the face, sometimes arched; cheek bones high, and widely separated; angle of the jaw broad, and chin square. The accompanying head is that of Ong-patonga, (*Big Elk*,) chief of the Omawhaw Indians.[1] Dr. Morton divides the American race into two families;—the American and Toltecan;—the latter embracing the civilized nations of Mexico, Peru, and Bogota.[2]

they are said to be sometimes as fair as the Malays, and the savage Dyaks of Borneo appear to belong to the same family. Dr. Morton thinks it not improbable, as suggested by Dr. Prichard, that the Alfores are but a branch of the Australian stock.—Crania Americana, p. 95.

[1] Godman's American Natural History, Philad., 1826–1828.

[2] Crania Americana, p. 83, Philad., 1839.

e. *Malay Race.*

The *Malay* or *Australian race*, *Tawny man* of Gmelin, is admitted by many naturalists, owing to the difficulty of referring it either to the Caucasian Indian, or the Chinese Mongolian in its vicinity. This Malay variety extends from Malacca to the most remote islands of the great Indian and Pacific Ocean, from Madagascar to the Maldives inclusive; inhabits Sumatra, Java, Borneo, Celebes, and adjacent islands; the Molucca, Ladrone, Philippine, Marian, and Caroline groups; New Holland, Van Diemen's Land, New Guinea, New Zealand, and the various islands scattered through the South Sea. It is termed *Malay*, because supposed to have proceeded originally from the Peninsula of Malacca, and to have spread thence over the adjacent islands,—a supposition, which is not confirmed by history: on the contrary, according to Mr. Marsden, it is clearly demonstrated, that the Malays went from Sumatra to Malacca in the twelfth century. No well-marked common characters can be assigned to this variety; for, under the term *Malay*, races are included, which seem to differ materially from each other; so much so, indeed, as to induce many naturalists to refuse the admission of the Malay as a distinct variety. Their colour may be said to be brown, in various shades, from a light tawny to almost black: the forehead is low and round; the nose full and broad; nostrils wide; mouth large; hair thick, crisp, and always black, as well as the iris. Fig. 314 exhibits an individual of this race; it is the head of a New Zealand chief. Cuvier,[1] Rudolphi,[2] Virey, and others consider the Malay variety to be a mixture of the Mongol of Asia and the negro of Africa. Dr. Morton[3] divides the Malay race into two families—the Malay, and Polynesian.

In New Guinea, and the small islands around, the *Papuas* are found, who resemble the negroes still more strongly; and similar races are met with in the Archipelago of the Holy Ghost, and in the isles of Andaman and Formosa. They are presumed to belong really to the negro race, and to have descended perhaps from individuals of that variety, who have wandered, or been driven, from their original settlements. Some of them resemble the Guinea negro in every particular.

Since the work of Blumenbach was issued, many other races have been added to those admitted by him; especially by Virey,[4] Desmoulins,[5] Malte-Brun,[6] Bory de Saint-Vincent,[7] Gerdy,[8] Broc,[9] and Pickering,[10] who,—like their predecessors,—dissatisfied with the divisions that had been adopted by naturalists, have taken colour as the basis of theirs. For *race* they substitute *sub-genus;* of which they admit four,—the *white*, *yellow*, *negro* or *black*, and *red*.

[1] Op. cit.

[2] Grundriss der Physiologie, th. 1, Berlin, 1821.

[3] Op. cit., p. 6.

[4] Histoire Naturelle du Genre Humain., 2de édit, Paris, 1824.

[5] Hist. Naturelle des Races Humaines, Paris, 1826.

[6] Géographie Universelle, Paris, 1816.

[7] L'Homme, Essai Zoologique sur le Genre Humain., 2de édit., Paris, 1827.

[8] Physiologie Médicale, tom. i.

[9] Essai sur les Races Humaines, p. 25, Paris, 1836.

[10] United States Exploring Expedition, during the years 1838. 1839, 1840, 1841, 1842, under the command of Charles Wilkes, U. S. N. The Races of Man and their Geographical Distribution, by Charles Pickering, M. D., &c., Boston and London, 1848.

The various classifications exhibit the vacillation that yet exists regarding the precise number of races which should be admitted. Every division must necessarily be arbitrary, and the individuals composing each variety be far from alike. We find the greatest diversity, for example, amongst the nations of the Caucasian variety, and even amongst any of its subdivisions. The Frenchman can be distinguished from the German, the Spaniard from the English, &c., and if we were to push the system of subdividing, which appears at present to be fashionable, we might constitute almost every nation of the globe into a distinct variety.

2. *Origin of the Different Races.*

It has been an oft agitated question, whether all the varieties amongst mankind must be regarded as belonging to the same species,—the differences which we observe being referable to extraneous circumstances acting through a long succession of ages; or whether they must not be regarded as distinct species *ab origine*. By many, the discussion of the subject has been esteemed not only unnecessary but profane, inasmuch as the sacred historian has unequivocally declared, that all mankind had a common origin. Such a declaration, however, is not so clear as has been argued; for the sacred writings inform us, that Cain sought his wife in another land—and, therefore, it might be presumed, in one not belonging to his own immediate family.[1] We have already remarked, however, that in accordance with biblical history this can scarcely be a question, that concerns our first parents; but belongs exclusively to the family of Noah; for, in his descendants, all these varieties must have occurred. From the part of Asia, previously described, his immediate descendants must have spread abroad to the north and south, the east and west; Europe being peopled by the migratory hordes, which proceeded towards the northwest; and Africa by those from southwestern Asia. These migrations may have taken place by land, except in the case of our own continent, where a slight sea-voyage, of not more than thirty-nine miles, across Behring's Straits, even in frail vessels, would be sufficient to transport emigrants without much risk of misadventure; and even this short voyage would be rendered unnecessary during the winter season, the strait being solidified into a continuous mass of ice. Europe probably received its inhabitants long before navigation existed to any extent. Subsequently, when a coasting trade was first established,—to which the enterprise of nations would necessarily be limited in the first instance, until by improved vessels and a better system of management they were enabled to brave the terrors of the ocean, and undertake their adventurous voyages of discovery,—many of the coasts, especially of the Mediterranean, received swarms of emigrants, a circumstance, which accounts for the motley population, observable, at an early period, in these regions. Carthage, we know, was settled by the Phœnicians; and southern Italy and Spain, in this manner, received their Greek colonies. Dr. Cop-

[1] See, on this subject, a well-written and elaborate work, entitled "An Investigation of the Theories of the Natural History of Man, by Lawrence, Prichard, and others," &c. &c., by William Frederick Van Amringe, New York, 1848.

land[1] has even expressed his belief in the view, that this continent was visited "by Phœnician navigators, the greater part of whom settled in it, particularly in Mexico; and that the imperfect navigation of that era prevented many of the adventurers, if not all of them, from returning." The notion is, however, hypothetical.

The greatest difficulty has been,—to comprehend how the Caucasian and Ethiopian varieties could have originated from the same source. The other varieties of mankind, if we exclude the negro, could be referred, with less hesitancy, to the same primitive stock,—the changes being caused by adventitious circumstances operating for an immense period; but it has seemed to many naturalists impossible to suppose, that the characters of the negro could, by any process, become converted into those of the European, and conversely.

Under the view of the unity of the human race, it might be presumed, that the people of antediluvian times had but few physical differences, and constituted one large family, modified, perhaps, but not materially, by circumstances,—the two antithetical races, the white and the black,—first arising in postdiluvian periods. If we adopt this view, the question regarding the difference of *species* between the white and black would require no agitation.[2] But how are we to explain the essential differences as to form and colour, which we notice amongst the nations of the earth?

In the infancy of anthropology, it was asserted, that the white races inhabit the cold and temperate regions of the earth, whilst the tawny and darker are situate under a more vertical sun. Within certain limits, the sun is doubtless possessed of the power of modifying colour. The difference between one, who has been for some time exposed to the rays of a tropical sun, and his brethren of the more temperate climates, is a matter of universal observation. The inhabitant of Spain is distinguishable from the French, German, English, &c.; and we can understand, why the Southern Asiatic and African women of the Arab race, when confined within the walls of the hareem, may be as white as the fairest Europeans. There are many exceptions, however, to the notion which has prevailed, that there is an exact ratio between the heat of the climate and the blackness of the skin. For example, at the extreme north of Europe, Asia, and America, we find the Laplanders, Samoiedes, Esquimaux, &c., with the skin brown, and the hair and iris black; whilst, in the vicinity of the Laplanders, are the Fins,—a people of large stature compared with the Laplanders, with fair skins and bluish-gray eyes. In the same manner, to the south of the Greenlander,—of short stature, brown skin, and dark hair,—is the tall and fair Icelander. Many distinct tribes exist in the interior of Africa having a red or copper hue, with lank black hair, and in the midst of black varieties of the species. A similar fact was observed by Humboldt in different parts of South America. Again, the negro race is not always found in the torrid zone. On our own continent, none have ever been met with, except what have been imported; and these, after

[1] Notes to translation of Richerand's Physiology.

[2] See, on the subject of hybridity as a test of specific affiliation, the remarks at pages 457 and 468 of this volume.

repeated descents, have retained their original character; whilst, as we have seen, negroes are met with in Australia under a climate as cold as that of Washington. The fact of the slight mutation effected by ages on the character of a race is strikingly shown by the circumstance before referred to,—that in some of the monuments of Egypt, visited by Belzoni and Champollion, representations presumed to be nearly four thousand years old of the negro exhibit the features to be almost identical with those of the same race in the present day. The Jew affords an example of the same immutability, as well as the Esquimaux, who strikingly retains the evidence of his Kalmuck origin. Complexion and, to a certain extent, figure are doubtless modified by climate, but the essential characters of the organization remain little if at all changed. Volney has fancifully supposed, that the elongated visage of the negro is owing to the wry face habitually made under exposure to the rays of the sun. Independently, however, of the objection, that this would be insufficient to account for the striking peculiarities of the negro head, it has already been remarked, that these peculiarities do not exist among other races inhabiting equally hot climes; and that the negro himself is not confined to those climates, and ought, consequently, to lose the *museau* or snout, when the country is so cool as to render the wry face or *moue* unnecessary. It may then, we think, be concluded, that the evidence in favour of the colour of the negro, the red man, or the tawny, being produced directly or indirectly by the solar rays, is insufficient to establish the point. One important argument in the negative is the fact, that in all cases the children are born fair, and would continue so, if not exposed to the degree of solar heat, which had produced the change in their progenitors.

In addition to the influences of temperature, and climate, that of food, and of different manners and customs has been frequently urged, but without any precise results being deduced. The effect of difference in manners and customs is shown in the results of domestication on animals—as in the case of the wild and the disciplined horse; and of the bison and the ox—which last is regarded as the bison in a state of tameness. The precise cause of such modification we know not. It is not confined to the animal; but is signally evidenced in the vegetable. The flower of the forest, when received into the *parterre* and carefully nurtured, may develope itself in such a manner as to be with difficulty recognisable. The change seems to be produced by variation of climate and nutrition, but in what precise manner we know not. The important modifying influence of locality on the developement of the moral and physical powers has been more than once referred to. Perhaps the most remarkable examples are met with at the base of lofty mountains, particularly of the Alps, and in some of the unhealthy districts of France especially. One of these is *cretinism*, a singular case of malformation, with which we are happily unacquainted in the United States. This is a state of idiocy, which is remarkable in its subjects being always more or less deformed, and in its appearing to originate from local influences. The *crétin* has every characteristic of the idiot; and, in addition, is often distinguished by a large *goître* or swelling of the thyroid gland; by soft flabby flesh; and by shrivelled, yellowish,

or pale and cadaverous skin, covered, at times, with filthy cutaneous eruptions. The tongue is thick and pendant; the eyelids large and projecting; the eyes gummy, red, and prominent; the nose flat; the mouth gaping and drivelling; the face puffy, and at times, violet-coloured, and the lower jaw elongated. In several, the forehead is broad inferiorly, and flattened and retreating above, giving the cranium the shape of a cone rounded towards its smaller extremity. The stature of the cretin is generally small, scarcely ever exceeding four feet and a few inches; the limbs are frequently malformed, and almost always kept in a state of flexion. All the cretins are not affected with goître. Some have large and short, whilst others have thin, and long necks. Like the idiot, the cretin does not generally live long, scarcely ever surviving his thirtieth year. It has been estimated,[1] that in the valleys of Switzerland, the number of cretins at the present day amounts to eight thousand, who are completely idiotic, and to double or treble the number, who are more or less defective intellectually. Authors have differed in opinion as to the causes of this deplorable condition. It is observed almost exclusively in the deep and narrow valleys at the foot of lofty mountains, and in mountain gorges; and hence is common in that part of the Alps called the Valais or Wallais; in the valley of Aost, La Maurienne, &c. It is met with, too, at the foot of the mountains of Auvergne, the Pyrenees, the Tyrol, &c. De Saussure, Esquirol, Foderé, Rambuteau—and all who have had an opportunity of observing these miserable wrecks of humanity—believe, that the great cause is the concentrated, moist, and warm air, which prevails throughout almost the whole of the year in the valleys and mountain gorges where it is found to exist. That it is dependent upon locality is obvious, but how this acts we know no more than we do of the immediate cause of other endemic affections—intermittent fever, pellagra, beriberi, &c. &c.

After all, perhaps, the strongest arguments in favour of extraneous circumstances occasioning, in the lapse of ages, the different varieties, which we observe in the great human family, are those derived from the changes that must have occurred amongst many of the inferior animals. The dog, in its wild state, has always pretty nearly the same characters, —being covered with hair of the same colour: the ears and tail, and limbs, have the same shape, and it exhibits, apparently, the same powers and instincts; but, on this matter, our knowledge, derived from observation, is necessarily limited. Yet what a number of varieties are observed in the animal when it becomes domesticated; and how different from each other, in shape, colour, character of skin, and instincts, are the spaniel, hound, grayhound, pointer, mastiff, terrier, cur, pug, lap-dog, &c.; differences certainly as great as between the varieties of mankind.[2] These differences, it is presumable, may have been produced partly by the occurrence of accidental varieties, affecting perhaps a whole litter,—male and female; so that if these again were to be coupled, the variety, thus accidentally caused, might become permanent. Such accidental varieties occasionally occur in the human species, but they

[1] British and Foreign Medical Review, April, 1844, p. 514.
[2] Prichard's Natural History of Man, p. 53, Lond., 1843.

are soon lost, in consequence of the wise law that prevents individuals, within certain degrees of consanguinity, from marrying. It is by no means uncommon, for example, for different children of the same family, from some accidental cause, to be born with six fingers. The author has met with two families in each of which more than one individual was thus circumstanced; and Sir Anthony Carlisle[1] has detailed the remarkable case of a family from this continent, where the superfluity extended, in the case of a female, to two thumbs on each hand, and to six toes on each foot. She married and had several children, who, in their turn, became parents, and transmitted the peculiarity to the children to the fourth generation. Now, if the members of this family had continued to marry in and in, a new race of individuals might have been perpetuated, possessing the unnecessary additions in question. Under existing laws and customs it must always happen, that where such peculiarity exists in one parent only, it must soon become extinct; yet, as we have seen, it may be pertinacious enough to persist for some generations. Fortunately, also, it happens, that, as a general rule, no change, which occurs accidentally in the parent after birth, is liable to be extended to the progeny.[2] Were the rule other than it is, the most strange and innumerable varieties of races would arise. Where a limb had become distorted or amputated, a stock of one-limbed animals would be formed; the docked horse would propagate a mutilated colt; the operation of circumcision, performed on one parent, ought to be sufficient for the whole of his descendants, &c. &c.

In addition to this mode of accounting for the great number of varieties in animals of the same species, the influence of difference in manners and customs, to which allusion has already been made, has been brought forward; and it has been conceived, that the effect of civilization and refinement on the human race may be analogous to that of domestication on inferior animals. This kind of influence is said to be particularly observable amongst the inhabitants of Hindoostan, where, in consequence of the division into castes, the same condition of life, and the same occupation are continued without change through many successive generations. The artisans, who are a superior class, are of manifestly lighter complexion than the tillers of the soil; and in many of the islands of Polynesia, the same difference exists between the classes as in Hindoostan.

The believers, then, in the Mosaic account of the creation, and the deluge, must regard all the varieties of mankind to have descended from the same family,—that of Noah,—and the different changes, which have been impressed upon their descendants, to be results of extraneous influences acting through a long succession of ages, added to the production perhaps of accidental varieties, which may have occurred in the very infancy of postdiluvian existence, when the intermarriage of near relations was unavoidable, and such varieties would necessarily be perpetuated. The race of Ham appears to have been separated, if

[1] Philosoph. Transact. for 1814.

[2] The author has been informed by one who has had ample opportunity for observation, that when two deaf and dumb individuals marry, the defect is rarely, if ever, observed in their progeny: but that the contrary is the case with the born blind.

not wholly, at least in part, from their brethren by the malediction of Noah; and, whether we consider, that a physical alteration was comprised in the malediction, or that such alteration might occur accidentally, as in the cases of those with supernumerary toes and fingers, the very fact of intermarriage with the descendants of the other sons of Noah being prevented by the curse pronounced on Ham (for many commentators read Ham for Canaan), would necessarily lead to a perpetuation of the adventitious modification.

But, it has been asked, if all mankind have descended from one family, which of the varieties now extant must be regarded as their representative? On this we have nothing but conjecture to guide us. It has been supposed, by some, to be more probable, that the changes induced upon mankind have been rather in consequence of the progress from a state of barbarism to one of refinement than the reverse; and hence—it has been conceived—that variety ought to be considered primary, which, through all the vicissitudes of human affairs, has remained in the most degraded condition, and in its structure differs most materially from the one that has uniformly enjoyed the greatest degree of civilization. Upon this principle, the Ethiopian would have to be regarded as the original type of our first ancestors; and such is the opinion of Drs. Prichard and Bostock, and of M. Marcel de Serres[1] and others. Blumenbach, however, maintains the converse view. Bishop Heber, again, suggests, whether the hue of the Hindoo, which is a brownish-yellow, may not have been that of our first parents; from which the transition, he thinks, to the white and black varieties, might be more easy and comprehensible. Philology occasionally aids us in our historical deductions, but the evidence afforded by it has to be received with caution. The Hebrew names, like all original appellations, in perhaps all languages, are generally expressive, and therefore worthy of consideration in questions of this nature. The Hebrew word Adam, (אדם,) is not only the name of the first man, but it signifies man in the abstract, corresponding to the Greek, ανθρωπος, and the Latin, *homo*. We are told, in the sacred volume, that "in the day that God created man, in the likeness of God made he him; male and female created he them; and blessed them, and called their name Adam, in the day when they were created." The word Adam is derived from a Hebrew root, (אדם,) signifying "to be red," and accordingly, it has been thought probable, that the original hue of the first man was of that character.

The remarks already made render it unnecessary to inquire into the mode in which, according to the notions of Blumenbach,[2] Dr. S. S. Smith, of Princeton,[3] or Dr. Rush, the black colour of the Ethiopian has been produced. Blumenbach imagined, that the heat of the climate gives rise to an excessive secretion of bile; that in consequence of the connexion which exists between the action of the liver and the skin, an accumulation of carbonaceous matter takes place in the cutaneous vessels; and this process being continued for a succession of ages, the

[1] L'Institut., 13 Févr., 1850.
[2] De Gener. Human. Variet. Nat., edit. p. 66, Gotting., 1795.
[3] An Essay on the Causes of the Variety of Complexion and Figure in the Human Species, Philad., 1787.

black colour becomes habitual. Dr. Smith had a similar opinion; he thought that the complexion in any climate will be changed towards black, in proportion to the degree of heat in the atmosphere, and the quantity of bile in the skin; and, lastly, Dr. Rush, in one of the strangest of the strange views that have emanated from that distinguished, but too enthusiastic, individual, has attempted to prove, "that the colour and figure of that part of our fellow-creatures, who are known by the epithet of negroes, are derived from a modification of that disease which is known by the name of leprosy." The following are his deductions from "facts and principles" urged in a communication read before the American Philosophical Society in 1792:[1]—"1. That all the claims of superiority of the whites over the blacks, on account of their colour, are founded alike in ignorance and inhumanity. If the colour of negroes be the effect of a disease, instead of inviting us to tyrannize over them, it should entitle them to a double portion of our humanity, for disease all over the world has always been the signal for immediate and universal compassion. 2. The facts and principles which have been delivered, should teach white people the necessity of keeping up that prejudice against such connexions with them as would tend to infect posterity with any portion of their disorder. This may be done upon the ground I have mentioned without offering violence to humanity, or calling in question the sameness of descent, or natural equality of mankind. 3. Is the colour of the negroes a disease? Then let science and humanity combine their efforts, and endeavour to discover a remedy for it. Nature has lately unfurled a banner upon this subject. She has begun spontaneous cures of this disease in several black people in this country. In a certain Henry Moss, who lately travelled through this city, and was exhibited as a show for money, the cure was nearly complete. The change from black to a natural white flesh colour began about five years ago at the ends of his fingers, and has extended gradually over the greatest part of his body. The wool, which formerly perforated the cuticle, has been changed into hair. No change in the diet, drinks, dress, employments, or situation of this man had taken place previously to this change in his skin. But this fact does not militate against artificial attempts to dislodge the colour in negroes, any more than the spontaneous cures of many other diseases militate against the use of medicine in the practice of physic. To direct our experiments upon this subject, I shall throw out the following facts:—1. In Henry Moss the colour was first discharged from the skin in those places on which there was most pressure from clothing, and most attrition from labour, as on the trunk of his body, and on his fingers. The destruction of the black colour was probably occasioned by the absorption of the colouring matter of the rete mucosum, or perhaps of the rete mucosum itself; for pressure and friction, it is well known, aid the absorbing action of the lymphatics in every part of the body. It is from the latter cause, that the palms of the hands of negro women, who spend their lives at a washing-tub, are generally as fair as the palms of the hands in labouring white people. 2. Depletion, whether by bleeding,

[1] Transact. of the American Philosoph. Society, vol. iv.

purging, or abstinence, has been often observed to lessen the black colour in negroes. The effects of the above remedies in curing the common leprosy satisfy me that they might be used, with advantage, in that state of leprosy, which I conceive to exist in the skin of the negroes. 3. A similar change in the colour of the negroes, though of a more temporary nature, has often been observed in them from the influence of fear. 4. Dr. Beddoes tells us that he has discharged the colour in the black wool of a negro by infusing it in the oxygenated muriatic acid, and lessened it by the same means in the hand of a negro man. The land-cloud of Africa, called by the Portuguese Ferrino, Mr. Hawkins tells us, has a peculiar action upon the negroes in changing the black colour of their skins to dusky gray. Its action is accompanied, he says, with an itching and prickling sensation upon every part of the body, which increases with the length of exposure to it so as to be almost intolerable. It is probably air of the carbonic kind, for it uniformly extinguishes fire. 5. A citizen of Philadelphia, upon whose veracity I have perfect reliance,[1] assured me that he had once seen the skin of one side of the cheek inclining to the chin, and of part of the hand in a negro boy, changed to a white colour by the juice of unripe peaches, (of which he ate a large quantity every year,) falling, and resting frequently upon those parts of his body.

"To encourage attempts to cure this disease of the skin in negroes, let us recollect that, by succeeding in them, we shall produce a large portion of happiness in the world. We shall in the *first* place destroy one of the arguments in favour of enslaving the negroes, for their colour has been supposed by the ignorant to mark them as objects of divine judgment, and by the learned to qualify them for labour in hot and unwholesome climates. *Secondly.* We shall add greatly to *their* happiness, for however well they appear to be satisfied with their colour, there are many proofs of their preferring that of the white people. *Thirdly.* We shall render the belief of the whole human race being descended from one pair easy and universal, and thereby not only add weight to the Christian revelation, but remove a material obstacle to the exercise of that universal benevolence which is inculcated by it."

Of late, the question of the unity of the human family has been again agitated by distinguished individuals, and mainly on zoological grounds. Many years ago, it was ably argued by Mr. Lawrence,[2] whose views met with so much intolerance and persecution as even to affect his professional success, and social position,—that animals were created for special localities, to which they are often confined, unless conveyed elsewhere by human agency. "The question"—he remarks —"belongs properly to the domain of natural history and physiology;" and as such it has been recently examined by Professor Agassiz, Dr. Morton[3] and others of this country, who accord, in the main, with Mr.

[1] Mr. Thomas Harrison.

[2] Lectures on Comparative Anatomy, Physiology and Zoology, and the Natural History of Man, p. 166, Lond., 1844.

[3] Hybridity in Animals and Plants considered in reference to the question of the Unity of the Human Species, in Amer. Journ. of Science and Arts, vol. iii., Second series, 1847.

Lawrence. Professor Agassiz[1] emphatically declares it to be inconsistent with the structure, habits, and natural instincts of most animals to suppose that they could have migrated over any great distances; and that "he is satisfied it was never meant in the sacred writings, that all men originated from a single pair, or that animals had a similar origin from one common centre, or from single pairs:" and, he adds, that "this doctrine of a unique centre of origin and successive distribution of all animals is of very modern invention, and can be traced back for scarcely more than a century in the records of our science." These views have been strengthened by his recent examination of Lake Superior, which lead him to affirm,[2] that "all the fresh water fishes of the district under examination are peculiar to that district, and occur no where else in any other part of the world. They have their analogues in other continents, but nowhere beyond the limits of the American continent do we find any fishes identical with those of the district, the fauna of which we have been recently surveying." "If"—he adds—"we face the fundamental question, which is at the bottom of this particular distribution of animals, and ask ourselves, where have all these fishes been created, there can be but one answer given, which will not be in conflict and direct contradiction with the facts themselves; and the laws that regulate animal life. The fishes and all other fresh water animals of the region of the great lakes must have been created where they live. They are circumscribed within boundaries over which they cannot pass, and to which there is no natural access from other quarters. There is no trace of their having extended further in their geographical distribution at any former period, nor of their having been limited within narrower boundaries. It cannot be rational to suppose that they were created in some other part of the world, and were transferred to this continent, to die away in the region where they are supposed to have originated, and to multiply in the region where they are found. There is no reason why we should not take the present evidence in their distribution as the natural fact respecting their origin, and that they are, and were from the beginning, best suited for the country where they are now found."[3]

It must be admitted that the zoological facts brought forward in recent periods more especially are of great weight in determining the question whether all mankind were originally descended from one pair, and all animals distributed from a common centre; and that a strong case has been made out in favour of the negative view.[4]

[1] Christian Examiner, March, 1850, p. 185.

[2] Lake Superior; its Physical Characters, Vegetation, and Animals, compared with those of other and similar Regions, p. 375, Boston, 1850.

[3] See, also, Agassiz and Gould, Principles of Zoology, p. 179, Boston, 1848.

[4] Agassiz, on the Diversity of Origin of the Human Races, in Christian Examiner for July, 1850.

CHAPTER V.

LIFE.

The knowledge of the mode in which the various functions of the body are exercised constitutes the *science of life*. The manifestations of life have, consequently, been considered already. We have seen, that animal and vegetable substances possess the ordinary properties of matter, but that these properties are singularly controlled, so that they are prevented from undergoing the changes that inevitably occur as soon as they become deprived of vitality. The human body is prone to decomposition. It is formed of substances extremely liable to undergo putrefaction, and is kept at a temperature most favourable for such change; yet, so long as life exists, the play of the ordinary affinities is prevented, and this constant resistance to the general forces of matter prevails throughout the whole of existence, even to an advanced old age, when, it might be supposed, the vital forces must be enfeebled almost to annihilation. The case of solution of the stomach after death, described in the first volume of this work, is an additional and forcible evidence of such resistance. So long as life continues, the gastric secretions exert no action on the organ, but, when it becomes extinct, the secretions act upon it as they do upon other dead animal matter. What, then, is this mysterious power, possessed of such astonishing, incomprehensible properties? Our knowledge is limited to the fact above stated, that organized matter, in addition to the general physical and chemical forces, possesses one other,—the *vital force* or *principle* or *vitality*,—which, in activity, constitutes *life*. This force exists, not only in the whole, but in every part, of a living body; and its existence is evidenced by the unequivocal signs afforded by the various functions we have considered, as well as by others to be presently described. Yet it is not equally manifested in all organs; some appearing to be possessed of more vitality than others,—a result probably produced by diversity of texture, as it would seem irrational to admit a different kind of vital force wherever its manifestations appear to be modified.

Admitting the existence of this controlling force, what, it may be asked, are the functions through which it immediately acts in keeping up the play of the living machine? It has been elsewhere seen, that, in animals the reciprocal action of innervation and circulation is indispensable, and that if one of these functions be arrested, the other quickly ceases. This is only applicable, however, to animals; and it has been doubted, whether it applies to all and every part of them; whilst to the vegetable it is altogether inapplicable, unless we regard it, with some physiologists, as possessing a rudimental nervous system. The function of sensibility exhibits to us the mode in which the nervous system acts in connecting man with the objects around him, through

the agency of volition; but numerous other acts take place within him, altogether uninfluenced by volition, and yet indispensable for the maintenance of existence. These last acts are met with equally in the animal and vegetable; and hence a division has been made by Bichat,[1] into *animal life* and *organic life*:—the former evidenced by those functions that are peculiar to animals—sensibility and voluntary motion—which require the presence of a great nervous centre, that may receive from, and transmit to, the different parts of the body, the nervous irradiations,—the necessary excitants of the different functions:—the latter evidenced by those functions that are common to animals and vegetables, and are inservient to the nutrition of the frame, —as digestion, absorption, respiration, &c., all of which go on without any direct exercise of volition; and in the vegetable independently of all nervous influence.

Physiologists may, on this point, be divided into two classes;—they who consider, that the whole of the organic functions are under the government of the nervous influence; and they who think, that the nervous influence does not extend to all these functions, but only to the principal of them. The supporters of the first opinion believe, that the agents or conductors of the nervous influence are less and less dependent upon the nervous centres, when such exist, the lower the animal is situate in the animal kingdom, and the lower the function; but they consider the nervous influence to be indispensable to every living being, and to every part of such being. In support of this opinion, they are of course compelled to believe, either that a nervous system exists in the vegetable, or that there is a system, which appears to exert over every part of it an influence necessary for its life, and which is, consequently, analogous to the nervous system of animals. The organ of this influence is, by some, considered to be the *medulla* or *pith*;—whence medullary appendages set out to be distributed to every part of the vegetable, and which are especially abundant in such parts as are charged with very active functions,—as the flower. M. Brachet[2] maintains this idea, and compares the knots of the pith to the ganglions of the nervous system,—destruction of the pith, and especially of these knots occasioning the death of the parts, which receive their filaments from them. M. Dutrochet, again, considers, that nervous corpuscles exist in the pith of vegetables, which constitute the rudiments of a nervous system; but in the vegetable, this system is diffused, instead of being collected into a mass, as in the animal. The believers in the earlier formation of the nervous system in the fœtus will necessarily be in favour of the first opinion. The supporters of the second opinion,—that the nervous influence does not extend to all the organic functions,—assert, that it is chiefly exerted on those functions, which are of the highest moment,—the most elevated in animality; that it is less and less in the inferior functions, and ultimately ceases in the lowest acts,—those that immediately accomplish nutrition and reproduction; and the arguments they adduce in favour of their views are, that these lowest acts exist in every

[1] Recherches Physiologiques sur la Vie et la Mort, Paris, 1800.

[2] Recherches Expérimentales sur les Fonctions du Système Nerveux Ganglionnaire, &c., Paris, 1830.

living being—vegetable as well as animal; and that in the superior animal, and in man, there are many parts which do not appear to contain nerves. They, moreover, consider the nervous system as one superadded in living beings, not only for nutrition and reproduction, but also, where necessary, for sensation, motion, &c., and hence the prolongations or extensions of this system ought to be sent to the organs of the internal or nutritive functions, for the purpose of connecting them with those of the external or sensorial functions; and that in these connexions only innervation consists. In this view, consequently, the nervous influence associates the different parts of the organism; is but an indirect condition of life; exists in the upper animals only, and can in no way be invoked to account for vegetable life. The last is, in our view, the most accurate opinion. We cannot, in the present state of knowledge, admit the existence of nerves in the vegetable; certainly no such thing as a nervous centre is discoverable, and yet we find the most complicated acts of nutrition and reproduction exercised by it, and the principle of instinct as strikingly evidenced as in many animals. We are, therefore, irresistibly led to the conclusion, that nerve-power and life-power are by no means identical; that the manifestations of vitality are not dependent upon nervous influence, and that the nerves are added, in the upper animals, for other purposes than that of communicating vital properties to the parts. This deduction will be found confirmed by the facts to be hereafter mentioned, connected with the independence of the vital property of irritability of the nervous influence.

In the introductory remarks to the first volume of this work, the characters, that distinguish organized from inorganic bodies, were pointed out. All the characters of the former result from the influence of a vital principle, which produces a body of a definite magnitude, shape, structure, composition, and duration. There is, moreover, a power, possessed by bodies endowed with the living force, of being acted upon by certain stimuli, and of being thrown into movement without the participation of the will. This has, indeed, by some physiologists, been considered to be the sole vital property,—with what truth we shall see hereafter. An inquiry into its manifestations will aid us materially in determining whether or not the vital force be effected directly through the medium of the nerves, and will tend to confirm an opinion we have already expressed on this subject.

Prior to the time of Haller, the nervous system was looked to as the great source of power in the body; and the contractile action of the muscles,—described at length under the head of Muscular Motion,—was considered to be wholly derived from the nerves, which were supposed to transmit the power to the muscular fibre as it was called for,—accurately regulating the quantity supplied. Haller contended for a *vis insita*, a force of *irritability* or *contractility*, essentially residing in the muscles themselves, independently of any condition of the nervous system, and called into action by stimuli, of which the nervous influence is one,—contributing, however, like other stimuli, to exhaust it, instead of furnishing any fresh supply. We have elsewhere shown, that a muscle is capable of being thrown into contraction after a limb

has been removed from the body, and for a considerable period after the cessation of respiration, circulation, and consequently of innervation, provided the appropriate stimuli be applied, so as to excite the vis insita, which remains in the muscle for some time after dissolution; and if all the nerves, supplying the limbs of a frog, be divided and cut out close to the place where they enter the muscles, the muscles will still retain their contractility in as great a degree as when the nerves were entire. It has been affirmed by an excellent observer,[1] that after tying the femoral artery or vein, or dividing the sciatic nerve in frogs, the full strength of the muscles remained unaltered for several days—in one case as many as twelve. They, who believe that the contractility of muscles is wholly derived from the nervous system, maintain, however, that in such case the stimulus may still act through the medium of portions of nerves always remaining attached to the muscle, however carefully attempts may have been made to remove them; and some have supposed, that these nervous fibres may even constitute an essential part of the muscular fibre. The most satisfactory reply, that has been made to this argument, is the following experiment of Dr. Wilson Philip.[2] All the nerves supplying one of the hind legs of a frog were divided, so that it became completely paralytic. The skin was removed from the muscles of the leg, and salt sprinkled upon them, which, being renewed from time to time, excited contractions in them for twelve minutes: at the end of this time they were found no longer capable of being excited. The corresponding muscles of the other limb, in which the nerves were entire, and of which, consequently, the animal had a perfect command, were then laid bare, and the salt applied to them in the same way. In ten minutes, they ceased to contract; and the animal had lost command of them. The nerves of this limb were now divided, as those of the other had been, but the excitability of the muscles to which the salt had been applied was gone. It excited no contraction in them. After the experiment, the muscles of the thighs in both limbs were found to contract forcibly on the application of salt. It excited equally strong contraction on both sides. In this experiment, the excitability of the muscles, whose nerves were entire, was soonest exhausted; and hence Dr. Philip[3] properly concluded, that the nervous influence, far from bestowing excitability on the muscles, exhausts it like other stimuli; and that excitability or irritability is a property of the muscle itself. This is confirmed by the fact, that, when the vital properties of nerves are destroyed by the application of narcotic substances, the irritability of the muscle to which they are distributed may remain for some time longer; so that they must be independent of each other. Of late, experiments have been performed by Harless,[4] on animals rendered completely insensible by inhalation of ether, which confirm this view. He found, that even when the nervous system had been rendered by the action of ether utterly incapable of conveying a galvanic stimulus applied either to the nervous centres or the nervous

[1] Valentin, Lehrbuch der Physiologie des Menschen, ii. 176-192.
[2] An Experimental Inquiry into the Laws of the Vital Functions, &c., p. 100, Lond., 1817.
[3] Lond. Med. Gazette, for March 18 and 25, 1837.
[4] Müller's Archiv., H. ii., s. 228, Jahrgang, 1847.

trunks; the same stimulus, applied directly to the muscles, would immediately throw them into powerful contraction. Dr. Madden, too, communicated some years ago, to the British Association at its meeting in Edinburgh, the results of the agency of narcotics in destroying the power of nervous conduction, without diminishing muscular contractility in an equal degree.[1]

The opinion of Professor Müller is, that if muscular irritability be not dependent upon the brain and spinal cord, they supply some influence essential to its exercise; and in confirmation of this he lays much stress on the loss of irritability by muscles within a few weeks after the section of their nerves. This, however, has been shown by Dr. J. Reid[2] to be owing to the altered nutrition consequent on their disuse. He divided the spinal nerves as they lie in the lower part of the spinal canal in four frogs, and both posterior extremities were thus insulated from their nervous connexions with the cord. The muscles of the paralysed limb were daily exercised by a weak galvanic battery; whilst those of the other limb were permitted to remain quiescent. This was continued for two months; at the end of which time the muscles of the exercised limb retained their original size and firmness, and contracted vigorously, whilst those of the quiescent limb had shrunk to at least one-half of their former bulk, and presented a marked contrast with those of the exercised limb. The muscles of the quiescent limb still retained their contractility, even at the end of two months; but Dr. Reid thought there could be little doubt, that, from their imperfect nutrition, and the progressing changes in their physical structure, this would in no long time have disappeared, had circumstances permitted the prolongation of the experiment.

It seems that this essential characteristic of living bodies is a distinct vital property, not confined, as Haller supposed, to the muscular structure, but existing over the whole body. In favour, again, of its not being dependent upon the nerves, we have the fact of its presence in the vegetable as well as in the animal. Many plants exhibit the power in a remarkable manner. The barberry bush is one of them. In this flower, the six stamens, spreading moderately, are sheltered under the concave tips of the petals, till some extraneous body, as the feet or trunk of an insect in search of honey, touches the inner part of each filament, near the bottom. The irritability of that part is such, that the filament immediately contracts there, and consequently strikes its anther, full of pollen, against the stigma. Any other part of the filament may be touched without this effect, provided no concussion be given to the whole. After awhile, the filament retires gradually, and may be again stimulated; and when each petal, with its annexed filament, has fallen to the ground, the latter, on being touched, shows as much irritability as ever. In another plant,—*Cistus helianthemum*, *dwarf cistus* or *lesser sunflower*,—the filaments, when touched, execute a motion, the reverse of that of the barberry. They retire from the style and lie down, in a spreading form, upon the petals.

[1] Brit. and For. Medico-Chirurg. Review, July, 1848, p. 245.
[2] Edinburgh Monthly Journal of Med. Science, May, 1841.

Owing to the possession of this property, *Apocynum androsæmifolium* or *dogsbane* is extremely destructive to insect life. Attracted by the honey on the nectary of the expanded blossom, the instant the trunk of the fly is protruded to feed on it, the filaments close, and, catching the fly by the extremity of its proboscis, they detain the insect until its struggles end in death occasioned apparently by exhaustion alone. The filaments then relax, and the body falls to the ground.[1] These are only evidences, however, of particular parts possessing an unusual degree of irritability. The property exists in every part of the plant, and, as in the animal, is the essential characteristic of life.

It forms a medium of communication between the various parts of the living machine, and is excited to action by extraneous influences. All its movements, however, appear to be dependent upon the action of appropriate stimuli, and are, consequently, passively exercised.

1. INSTINCT.

There is a power, which has been conceived to be nearly allied to irritability; and is highly characteristic of organized bodies,—vegetable as well as animal,—whose movements or impulsions are active, and varied. To this power, the term *instinct* has been appropriated by Virey,[2] Fleming,[3] Good,[4] and others. It is an extension of the ordinary acceptation of the term; but enables us to understand the phenomena better than when we restrict it to those manifestations of man, or animals, that bear the semblance of reason. It is this power, which, according to those gentlemen, regulates the movements, that are requisite to obtain a supply of food, to remove or counteract opposing obstacles, and to fly from impending danger, or repair injuries. "In every organized system," says Dr. Good,[5] "whether animal or vegetable, and in every part of such system, whether solid or fluid, we trace an evident proof of that controlling, and identifying power, which physiologists have denominated, and with much propriety, the principle of life. Of its cause and nature we know no more than we do of the cause and nature of gravitation, or magnetism. It is neither essential mind nor essential matter; it is neither passion nor sensation; but though unquestionably distinct from all these, is capable of combining with any of them; it is possessed of its own book of laws, to which, under the same circumstances, it adheres without the smallest deviation; and its sole and uniform aim, whether acting generally or locally, is that of health, preservation, or reproduction. The agency, by which it operates, is that which we denominate or should denominate instinct, and the actions, by which its sole and uniform aim is accomplished, are what we mean, or should mean, by instinctive actions: or, to speak somewhat more precisely, instinct is the operation of the living principle, whenever manifestly directing its operations to the health, preservation or reproduction of a living frame, or any part of such frame. The law of instinct, then, is the law of the living principle; instinctive

1 Sir J. E. Smith's Introduction to Botany, p. 211.
2 Art. Instinct, in Dict. des Sciences Médicales, xxv. 367.
3 Philosophy of Zoology, vol. i. 14, Edinb., 1822.
4 Book of Nature, ii. 114, London, 1826. 5 Ibid., ii. 132.

actions are the actions of the living principle; and either is that power, which characteristically distinguishes organized from unorganized matter, and pervades and regulates the former, uniformly operating by definite means in definite circumstances to the general welfare of the individual system or of its separate organs, advancing them to perfection, preserving them in it, or laying a foundation for their reproduction, as the nature of the case may require. It applies equally to plants and to animals, and to every part of the plant, as well as to every part of the animal, so long as such part continues alive. It is this, which maintains, from age to age, with so much nicety and precision, the distinctive characters of different kinds and species; which carries off the waste or worn out matter, supplies it with new, and in a thousand instances, suggests the mode of cure, or even effects the cure itself, in cases of injury or disease. It is 'the divinity that stirs within us' of Stahl, the *vis medicatrix naturæ* of Hoffmann and Cullen and the physicians of our day, &c. &c."

Of the existence of this instinctive force we shall adduce a few examples from both the vegetable and animal kingdom. When the seed of a plant is deposited in the ground, under circumstances favourable for its developement, it expands, and the root and stem are evolved. The root descends into the ground, manifestly not from the laws of gravitation, but owing to some inherent force, inasmuch as it penetrates the earth, which is of much greater specific gravity than itself. The stem, too, bursts through the earth, and rises into the air, notwithstanding the air is of much less specific gravity; until having attained the height to which the action of the vital force limits it, its upward developement ceases. It rarely happens, however, that the root is capable of procuring nourishment sufficient for its future developement in immediate contact with it. It, therefore, sends out numerous filamentous radicles in all directions to search after food, and convey it to the proper organs. The number and direction of these filaments, and the distance to which they extend, are regulated by the necessities of the plant, and the supply of the soil. A strawberry offset, planted in sand, will send out almost all its runners in the direction in which the proper soil lies nearest; and few, and sometimes none, in the direction in which it lies most remote.[1] When a tree, which requires much moisture, has sprung up, or been planted in a dry soil, in the vicinity of water, it has been observed, that a much larger portion of its roots has been directed towards the water, and that when a tree of a different species, and which requires a dry soil, has been placed in a similar situation, it has appeared, in the direction given to its roots, to have avoided the water and moist soil. When a tree, too, happens to grow from seed on a wall, it has been seen, on arriving at a certain size, to stop for a while, and send down a root to the ground. As soon as this root has been established in the soil, the tree has continued increasing to a large magnitude. The fact has been often noticed with respect to the ash,—a tree, which, in consequence of the profusion of its seed, is found more often scattered in wild and singular places, than in any other not propagated by the agency of birds, or conveyed by the winds.

[1] Fleming, op. citat., p. 16.

We find, in all cases, that if the roots of a plant, spreading in search of nourishment, meet with interruption in their course, they do not arrest their progress, but either attempt to penetrate the opposing body, or avoid it by altering their direction. Dr. Fleming[1] states that he has repeatedly seen the creeping root of *Triticum repens* or *couch grass* piercing a potato, that had obstructed its course. It is well known, too, that roots will pass under a stone wall or a ditch, and rise up on the opposite side. A striking case of this nature was communicated to the author, by his venerable friend, the late Ex-President Madison. The wooden pipes, for the conveyance of water to Mr. Madison's establishment, having become obstructed, they were carefully examined; when it was found, that the roots of a honeysuckle, growing immediately above a plug, made of the wood of *Liriodendron tulipifera* or *American poplar*, which is of soft consistence, had penetrated the plug in various places to reach the water, and formed an agglomerated mass in the pipe which completely precluded the passage of water along it.

The nearest approximation to these manifestations of instinct in the animal, occurs in the formation of the new being, and in the first actions that take place after birth. From the moment of the admixture of substances furnished by the parents at a fecundating copulation, there must be a force existing in the embryo, which directs the construction and arrangement of its organs after a definite manner; and always according to that peculiar to the species. In the egg, this is seen most distinctly. The germ of the chick is surrounded by the nourishment requisite for its formation. Organ after organ is successively evolved, until the full period of incubation is accomplished, when the young animal breaks the shell. At this time, it has within it a portion of nutriment derived from the yolk drawn into its body. This supplies its wants for a short period; but it soon becomes necessary, that it should select and collect food for itself, and we observe it throwing its various organs into action for prehension, mastication, deglutition, &c., as if it had been long accustomed to the execution of these functions. In the formation of the human fœtus in utero the same instinctive action is observable in the successive evolution of organs, and in the limitation of the body to a determinate shape, size, structure, &c.; and when these requisites have been attained, the child bursts the membranous envelope, and is extruded, to maintain thenceforth an existence independent of the mother. More helpless, however, than the young of the animal kingdom in general, the infant requires the fostering care of the parent for the purpose of supplying it with the necessary nutriment; but as soon as food is conveyed to the lips, the whole of the complicated process of deglutition is effected for the first time, with the same facility as after long practice. As we descend in the animal kingdom, we find these inward actions that constitute instinct more and more largely exhibited. In the quadruped, it is not necessary, that the nipple should be applied by the mother to the mouth of the new-born animal. It is sought for by the latter; discovered, and seized hold of, by the appro-

[1] Op. citat., p. 18.

priate organ of prehension, the mouth. The lips are applied; the air is exhausted; and the milk flows according to exact principles of hydrostatics, but without the animal having the least knowledge of the physical process it accomplishes. Naturalists, indeed, assert, that before the calf has been more than half extruded from the mother, it has been seen to turn around, embrace and suck the maternal teat. As we descend still farther in the scale of creation, we discover the manifestations of instinct yet more signally developed; until, ultimately, in the very lowest classes of animals, the functions are exercised much in the same manner as in the vegetable; and appear to be wholly instinctive, without the slightest evidence of that intelligence, which we observe in the upper classes of the animal kingdom, and pre-eminently in man. This, however, applies only to the very lowest classes; for, a short way higher up the scale, we meet with apparent intelligence, united with instinct, in a manner that is truly surprising and mysterious.

Again, the similarity of the actions of the instinctive principle in the animal and vegetable is exhibited by the reparatory power which both possess when injuries are inflicted on them. If a branch be forcibly torn from a tree, the bark gradually accumulates around the wound, and cicatrization is at length accomplished. The great utility of many of our garden vegetables,—as spinach, parsley, cress, &c.—depends upon the possession of a power to repair injuries, so that new shoots speedily take the place of the leaves that have been removed. Similar to this is the reparatory process, instituted in the lobster that has lost its claw, the water-newt that has lost an extremity, or an eye; in the serpent deprived of its tail, and the snail that has lost its head. These parts are reproduced as the leaves are in the spinach or parsley. Few animals, however, possess the power of restoring lost parts; whilst all are capable of repairing their wounds when not excessive, and of exerting a sanative power, when labouring under disease. If a limb be torn from the body,—provided the animal should not die from hemorrhage, a reparatory effort is established, and if the severity of the injury should not induce too much irritation in the system, the wound gradually fills up, and the skin forms over it. To a lesser extent we see this power exerted in the healing of ordinary wounds, and cementing broken bones; and although it may answer the purpose of the surgeon to have it supposed, that he is possessed of healing salves, &c., he is well aware, that the great art in these cases is to keep the part entirely at rest, whilst his salves are applied simply for the purpose of keeping the wound moist; the edges in due apposition, where such is necessary; and preventing extraneous bodies from having access to it;—his trust being altogether placed in the sanative influence of the instinctive power situate in the injured part, and in every part of the frame.

It is to this power, that we must ascribe all the properties, assigned to the famous *sympathetic powder* of Sir Kenelme Digby,—which was supposed to have the wonderful property of healing wounds, when merely applied to the bloody clothes of the wounded person, or to the weapon that had inflicted the mischief;—a powder, which, at one time,

enjoyed the most astonishing reputation.[1] The wound was, however, always carefully defended from irritation by extraneous substances; and it has been suggested, that the result furnished the first hint, that led surgeons to the improved practice of healing wounds by what is technically called the *first intention*. It is to this instinctive principle, so clearly evinced in surgical or external affections, but at times, not less actively exerted in cases of internal mischief, that the term *vis medicatrix naturæ* has been assigned; and, whatever may be the objections to the views entertained regarding its manifestations in disease, that such a power exists can no more be denied than that organized bodies are possessed of the vital principle. We have too many instances of recovery from injuries, not only without the aid of the practitioner, but even in spite of it, to doubt for a moment, that there is, within every living body, a force or impulse manifestly directed to the health and preservation of the frame, and of every part of it.

So far, then, it is manifest, the instinctive actions of the animal and vegetable are exerted according to the same laws, and probably through similar organs. This, at least, applies to the lowest of all animated beings, where the difference between them and the vegetable is small indeed. It applies equally to the human fœtus, which can be considered but to vegetate during the greater part of utero-gestation; and even for some time after birth its actions are purely instinctive, and differ but little from those of the vegetable, except that, owing to the morphology of its nervous system, the acts are of a more complicated character. It is only when the brain has become duly developed, and the external senses fully so, that it exhibits so decidedly the difference between those acts, which it had previously accomplished instinctively, and the elevated phenomena of sensibility, which man enjoys so pre-eminently, but are likewise possessed, to a greater or less extent, by the whole animal creation.

The cells of the ordinary honeycomb are intended for the larvæ of the different varieties of the occupants of the hive. These cells are usually placed horizontally, with their mouths opening towards the sides of the hive. The bottom of the cells, instead of forming one flat square, is composed of three lozenge-shaped pieces, so united as to make the cell end in a point; consequently, the whole forms an hexagonal tube, terminating in a pyramidal cavity. If the two cells had been a single hexagonal tube, intersected in the middle by a flat, instead of a pyramidal, division, not only would the shape have failed to answer the purpose of the bees, but more wax would have been expended in its construction. Hence, it would seem, that both the body and base of the tube are adapted for their object; the greatest strength and the greatest capacity being obtained with the least expenditure of wax in an hexagonal tube with a pyramidal base. Réaumur, when inquiring into the habitudes of these industrious animals, requested König, an able mathematician, to solve the following question:—Among all hexa-

[1] A late discourse made in a solemn assembly of nobles and learned men at Montpellier in France; by Sir Kenelme Digby, Knight, &c., London, 1658.

gonal tubes with pyramidal bases, composed of three similar and equal rhombs, to determine that which, having the same capacity, can be constructed with the least possible quantity of matter? König, not aware of the precise object of Réaumur's inquiry, solved the problem, and found,—that if three rhombs or lozenges are so inclined to each other that the great angles measure 109° 26′, and the little angles 70° 34′, the smallest possible quantity of matter will be needed. Maraldi measured the angles actually formed at the bottom of a cell, and found that the great angles gave 109° 28′ and the little 70° 32′.[1] All this, however, may be ascribed to blind instinct, proceeding uniformly in the same track, without any evidence of the admixture of reason; but we have innumerable instances, in the same insects, to show, that their operations are varied according to circumstances, and that intelligence is manifestly expended in the adaptation of means to definite purposes. Of this we shall give but one example. Huber, whose inquiries into this part of entomology have been singularly minute and accurate, having had great ravages committed on his hives by the *sphinx atropos* or *death's-head moth*, determined to construct a grating, which should admit the bee but not the moth. He did so, and the devastation ceased. He found, however, that in hives, not protected by his agency, the bees had adopted a similar expedient for their defence; and these defences were variously constructed in different hives. "Here, was a single wall whose opening arcades were disposed at its higher part; there, were several bulwarks behind each other, like the bastions of our citadels: gateways, masked by walls in front, opened on the face of the second rows, while they did not correspond with the apertures of the first. Sometimes, a series of intersecting arcades permitted free egress to the bees, but refused admittance to their enemies. These fortifications were massy, and their substance firm and compact, being composed of propolis and wax."

It would be endless, however, and beyond the design of this work, to enumerate the various evidences of intelligence exhibited by the insect tribe, in fulfilling the ends for which they have been destined by the Great Author of nature.

In all our reasonings on the subject of instinct, we must be compelled to admit, in the case of most animals at least, a degree of intelligence that strikingly modifies those actions, the impulse to which is doubtless laid in organization. The precise line of demarcation between instinctive acts and reason cannot, however, be established; and this has led some philosophers to call in question the existence of the former. It is owing to the union of intelligence with instinct, that we find animals accommodating themselves to circumstances, so that if prevented from adopting the habits that belong to the species, they have recourse to others as similar as possible. Thus, if a bird be prevented from building its nest in a particular situation, or from obtaining the material, which birds of its own species employ, it has recourse to other materials and to another situation, as like those that are appropriate

[1] See, also, Mr. Maclaurin, Philosophical Transactions, vol. ix.; and Rev. Sydney Smith, Elementary Sketches of Moral Philosophy, p. 242, Lond., 1850.

to it as is practicable. The rook usually and instinctively builds its nest on the summit of the tallest trees: but Dr. Darwin,—who is one of those that call in question the influence of instinct,—asserts, that in Welbourn churchyard, a rookery was formed on the outside of the spire, and on the tops of the loftiest windows. There had formerly been a row or grove of high trees in the neighbourhood, which had been cut down; and, in consequence, the birds exhibited the union of intelligence with instinct, by building on the lofty spire and windows. In like manner, the jackdaws of Selbourne, according to Mr. White, not finding a sufficiency of steeples and lofty houses on which to hang their nests in that village, accommodated themselves to circumstances, and built them in forsaken rabbit burrows.[1] In Africa, which abounds with numerous beasts and birds of prey, all the feebler species of the feathered tribe would seem to have contrived some means of protection and security for their reproduction. Some so construct their nests, that they can only be entered by one small aperture; others suspend them from the extremities of small branches of trees. A species of *loxia* always hangs its nest from a branch extending over a river or pool, the opening into its long neck almost touching the water. "A note in my Journal,"—says Sir John Barrow,[2]—"observes, that the sparrow, in Africa, hedges round its nest with thorns; and even the swallow, under the eaves of houses, or in the rifts of rocks, makes a tube to its nest of six or seven inches. The same kind of birds in Northern Europe, having nothing to fear from monkeys, snakes, or other noxious animals, construct open nests; and I ask is this difference the effect of mere accident or of design? Is it, I might have added, the effect of imitation or observation?"

By Stahl,[3] and the animists in general, as well as by more recent philosophers, all the phenomena of instinct have been referred to experience, so obscure as not to be easily traceable, but not the less certainly existent. The insect tribes, however, furnish us with many cases where the young beings can never see their parents, and can, of course, derive no benefit from the experience of progenitors; yet their habits are precisely what they have probably ever been; so uniform, indeed, as to compel us to refer them to some constant impulse connected with their special organization, and, consequently, instinctive. In support of the existence of these natural impulsions, the common occurrence of a brood of young ducks, brought up under a hen, may be mentioned.[4] These little beings, soon after they have broken the shell, and contrary to all the feelings and instincts of the foster-mother, seek the water, and suddenly plunge into it, whilst the hen herself does not dare to follow them. By what kind of experience or observation, —it has been asked,—by what train of thought or reasoning has the scarcely fledged brood been able to discern that a web-foot adapts them for swimming? Any experience they can have derived must have

[1] Natural History of Selbourne, with additions, by Sir W. Jardine, Amer. edit., p. 82, Philada., 1832.
[2] An Autobiographical Memoir of Sir John Barrow, Bart., p. 193, Lond., 1847.
[3] Theoria Vera Medica, Hal., 1737.
[4] Good's Book of Nature, ii. 118, Lond., 1826.

taught them to shun the water; yet, notwithstanding this, instinct points out to them habitudes for which they are adapted, and its indications are obeyed in spite of every kind of counter-experience. It is impossible to refer these acts to imitation, for there is no opportunity afforded for it. Sir James Hall, cited by Mr. Dugald Stewart in his "Lectures," hatched some chickens in an oven; and within a few hours after the shells were broken, a spider was turned loose before the newly-hatched brood, which had not proceeded many inches, before it was descried by one of them, and devoured.[1] Attempts have occasionally been made to domesticate the *wild turkey* of this continent, by bringing the young up under the common turkey, but they have always resumed the way of life to which instinct has directed them, when opportunity offered; in accordance with the Horatian maxim:

"Naturam expellas furcâ, tamen usque recurret."

Mr. Madison reared, with great care, a young hawk, which, for a long time, associated with the young of the poultry, without exhibiting the slightest carnivorous or migratory propensity, until, on one occasion, whilst some of his friends were admiring its state of domestication, it suddenly arose in the air, darted down, and seized a chicken, with which it flew to a neighbouring tree, and, after it had finished its repast, took flight, and was never seen afterwards.

Instinct, then, is possessed by every organized body, animal and vegetable; whilst intelligence is the attribute of those only that are endowed with a certain nervous developement. The two are, therefore, manifestly distinct;—the former predominating over the latter in the lower classes of animals; whilst, in the upper classes, intelligence becomes more and more predominant, until, ultimately, in man, it is so ascendant as to appear to be the main regulator of the functions: indeed, some have altogether denied the existence of instinct in him. Instinct is seated in every part of a living body; is totally independent of the nervous system; occurs in the vegetable and the zoophyte unprovided with nerves, or at least in which nerves have never been discovered; whilst intelligence is always accompanied by a nervous system, without which, indeed, its existence is incomprehensible. How can we, consequently, accord with those physiologists who place the seat of instinct in the organic nervous system, or in the reflex or excitory motory system of nerves; and that of intelligence in the brain? Where is the organic nervous system of the zoophyte, and *à fortiori* of the vegetable? Or how can we admit the seat of the various instincts to be in the encephalon, seeing that we have them exhibited where there is neither encephalon nor any thing resembling one! The acephalous fœtus undergoes its full developement in other respects in utero, with the same regularity as to shape and size as the perfect fœtus; and can we deny it the existence of instinct? Yet, in the upper classes of animals especially, many of the manifestations of instinct are effected through the nervous system, which, in them, as we have elsewhere seen, seems to hold in control the various functions of the frame, and

[1] Rev. Sydney Smith, Op. cit., p. 243.

to be one of the two great requisites for the existence of vitality. The instinctive action in the appropriate organ, which gives rise to the internal sensations of hunger, thirst, &c., is communicated to the great nervous centres by the nerves; the encephalon responds to the impression, and excites, through the medium of the nerves, the various organs into action which are calculated to accomplish the monitions of the instinct.

What is the nature of this instinctive property? Of this we know no more than we do of the nature of life, of which it is one of the manifestations. It is equally inscrutable with the imponderable agents, light, caloric, electricity, and magnetism, or with the mode of existence of the immaterial principle that gives rise to the mental phenomena: we see it only in its results, which are, in many cases, as unequivocal as those produced by the agents referred to. All, perhaps, that we are justified in concluding is—with Dr. Good—that instinct is the operation of the principle of organized life, by the exertion of certain *natural* powers, directed to the present or future good of the individual, whilst reason is the operation of the principle of intellectual life, by the exercise of certain *acquired* powers directed to the same object;—that the former appertains to the whole organized mass as gravitation does to the whole unorganized; actuating alike the smallest and the largest portions; the minutest particles and the bulkiest systems; and every organ, and every part of every organ, whether solid or fluid, so long as it continues alive;—that, like gravitation, it exhibits, under special circumstances, different modifications, different powers, and different effects; but that, like gravitation, it is subject to its own division of laws, to which, under definite circumstances, it adheres without the slightest deviation; and that its sole and uniform aim, whether acting generally or locally, is that of perfection, preservation, or reproduction.

In this view, *reason* demands discipline, and attains maturity: *instinct*, on the contrary, neither requires the one, nor is capable of attaining the other. It is mature from the first, and equally so in the infant as in the adult.

2. VITAL PROPERTIES.

The great cause of all those mysterious phenomena, that characterize living bodies, and distinguish them by such broad lines of demarcation from the dead, has been a theme of anxious inquiry in all ages; and has ever ended in the supposition of some special abstract force, to which the epithet *vital* has been assigned, and which has received various appellations. Hippocrates designated it by the terms φυσις, and ενορμων; Aristotle styled it the *animating* or *motive and generative principle;* Van Helmont, *archæus;* Stahl, *anima;* Barthez and Hunter, *vital principle*, &c. &c. Yet, as Dr. Barclay[1] has observed, all physiological writers—ancient and modern—seem to be agreed, that the causes of life and organization are utterly invisible, whether they pass under the name of *animating principles*, (Aristotle, Harvey, &c.,) *vital*

[1] An inquiry into the Opinions, ancient and modern, concerning Life and Organization, p. 519, Edinb., 1822; and The Muscular Motions of the Human Body, p. 261, Edinb., 1808.

principles, (Barthez,) *indivisible atoms*, *spermatic powers*, *organic particles* or *organic germs*, (Buffon,) *formative appetencies* or *formative propensities*, (Darwin,) *formative forces*, (Needham,) *formative nisus* or Bildungstrieb, (Blumenbach,) *pre-existing monads*, (Leibnitz,) *semina rerum*, (Lucretius,) *plastic natures*, (Cudworth,) *occult qualities*, or certain unknown chemical affinities. "All seem agreed, that whatever they be, they have been operating since the world began, and throughout the world operating regularly, without intermission, in various places at the same time. All seem agreed, that their modes of operation are strictly methodical; that they seem to act on definite plans, and actually exhibit specific varieties of chemical combination, and mechanical structure, which human intelligence cannot comprehend, much less explain. From their mutual dependence and other relations subsisting between them, all seem to speak as if they were subject to one great cause, which regulates and harmonizes the whole. All seem to speak of this great cause as if it were eternal, omnipotent, omnipresent; whether it be the element of fire, of air, or of water, or whether it be fate, nature, necessity, or a God."

By virtue of this principle or force of life,—the *biod* of Baron von Reichenbach[1]—every organized tissue is possessed of certain *properties*, to which the term *vital* has been assigned. Regarding the precise number of these properties, physiologists are not agreed. Whilst some have reckoned many; others have admitted but one. All the functions, which we have hitherto considered, are under the influence of life, and are products of the vital properties seated in the tissues; but we do not consider them to be directly caused by these properties. Digestion, for example, is executed by a series of organs, all of which are conducive to a certain result,—the aggregate constituting the function of digestion. The result of the action of the salivary gland is very different from that of the liver; yet both operations are vital, but modified by the different organization of the two glands. We do not ascribe the difference to a difference in the vital properties of the glands. These are probably the same in both; and are seated in the primary tissues, of which all the more compound textures and organs are built up. They are primary or fundamental properties of living matter.

Stahl, having observed obscure, oscillatory movements, alternate contraction and expansion in certain parts of the body, either during the exercise of a function, or on the application of some external agent, conceived, that every part of the frame is, at all times, more or less susceptible of similar movements. These movements he called *tonic;* their effect upon the organs *tone*, and the property by which they were induced he esteemed peculiar to organization, and called *tonicity*. This vital property, he conceived, influences the progression of the fluids in the vessels; the phenomena of exhalation and absorption; and is totally distinct from the properties possessed by inorganic bodies.

Haller[2] admitted two vital properties, very different from each other,

[1] Physico-Physiological Researches on the Dynamics of Magnetism, Electricity, Heat, Light, Crystallization, and Chemism in their relations to vital force, English edit. by Dr. Asburner, p. 224, Lond., 1850.

[2] Element. Physiol.; and Mémoire sur la Nature Sensible et Irritable des parties du Corps, Lausan., 1756.

which seemed to him to be equally elementary. By the one of these a living part exhibits itself to be *sensible*, or transmits to the sensorium an impression made upon it either by an extraneous body, or by its own internal and organic action; by the other, a part contracts in a manner appreciable to the senses, either by the influence of the will, or of some external or internal stimulus. The first of these he considered to be a special vital property, which he termed *sensibility;* and the second to be another, which he called *irritability*. Prior to his time the word irritability had been adopted by Glisson,[1] who had noticed the fact that living matter is acted upon by *irritants* of various kinds in a mode no wise analogous to physical and chemical motions; and hence he concluded, that every organ of the human frame possesses an inherent and peculiar force, which presides over its movements, and is requisite for the exercise of its functions. This force he called *irritability*. De Gorter[2] subsequently extended the views of Glisson, and applied them to the vegetable, affirming irritability to be the sole vital property of all organized bodies, vegetable as well as animal. The acceptation, given to the term by Haller, was consequently more limited. He restricted it to those motions of parts that fall under the observation of the senses;—such as the contraction of the voluntary muscles, heart, &c. He made numerous experiments on living animals, for the purpose of discovering what parts are possessed, and what are not, of the true properties of *sensibility* or *irritability*, and he concluded, that the former resides exclusively in the nervous,—the latter in the muscular, system. Dr. Marshall Hall[3] still employs the term in the restricted sense of Haller.

This celebrated theory, which formed so large a part of physiological science at one time, and is still an interesting topic to the physiologist, has been referred to in so many parts of this work, as to require but few comments here. We have seen, that many parts, regarded by Haller as insensible, are acutely sensible in disease; and that we cannot pronounce a part to be positively insensible, until we have applied every kind of irritant to it without effect. We have elsewhere defined sensibility to be an exclusive property of the nervous system; and have attempted to show, that irritability is a property of the muscular tissue —a *vis insita*—totally independent of the nerves, but of which the nervous fluid is an appropriate excitant. As, however, the vital properties of sensibility and irritability were restricted by Haller to the nervous and muscular systems, they were regarded to be insufficient for the explanation of the various living actions of the frame: the next step was to extend them to every part and to every tissue. It was found, for example, that on investigating the most minute movements of parts, these movements were always preceded by an impression, to which they seemed sensible, and which appeared to excite their actions. This general property, common to every living part, of receiving an impression, was called *sensibility;*—thus generalizing the property, which Haller had restricted to perceptivity by the mind. Every part

[1] De Ventriculo, in Manget. Bibl. Anatom. i. 80, Genev., 1699.
[2] Medicin. Compendium, Lugd. Bat., 1742.
[3] Art. Irritability, Cyclop. of Anat. and Physiol., July, 1840.

was said to be *sensible* to the blood sent to it for its nutrition. Again, every part was observed to move in consequence of the impression it received, sometimes in an apparent manner, as the heart; at others, too slightly for its movements to be recognized otherwise than by the results,—as in the case of the glandular organs; but always in a manner special to organized matter, and not analogous to any physical or chemical process. This motion was, therefore, referred to another force called *motility*, which was nothing more than irritability generalized. These two properties are alone admitted by most modern writers. Every organ is said to *feel* and to *move*, after its manner, in the performance of its function;—the stomach in digestion; the heart in propelling the blood; the muscle in contracting, and the nerve in transmitting sensitive impressions to the brain.

Many modern physiologists, whilst they admit the vital properties of sensibility and motility, have reckoned a greater number: this is owing to their having observed, that each part has its own peculiar mode of sensibility and motility; and when these modes have seemed to differ largely from each other, they have elevated them into so many special vital properties. The chief modern theories on the vital properties are those of Barthez, Blumenbach, Chaussier, Dumas, and Bichat. M. Barthez[1] admitted five, which we can do no more than enumerate,—*sensibility*, *force of contraction*, *force of expansion* or *active dilatation*, *force of fixed situation*, and *tonicity*. Blumenbach[2] also admitted five;—*sensibility*, *irritability*, *contractility*, *vita propria* or *proper force of life*, *nisus formativus—force of formation* or Bildungstrieb. M. Dumas[3] referred all the living phenomena to four vital properties; *sensibility*, *motility*, *force of assimilation*, and *force of vital resistance*. The theory of Bichat[4] on this subject requires a more detailed notice. He, also, admitted five vital properties; *organic sensibility*, *insensible organic contractility*, *sensible organic contractility*, *animal sensibility*, and *animal contractility*. *First*. *Organic sensibility* is the faculty possessed by every living fibre of receiving an impression, or of being modified by contact, the modification being restricted to the part that experiences it, and not transmitted to the brain. The term *sensibility* was adopted by Bichat because already established; and the epithet *organic* was added to affirm, that it is the exclusive attribute of organized bodies, and common to all. This property is not only modified in each organ—as the difference in their nutrition and functions demonstrates—but it adapts each organ to its appropriate external excitant, so that the salivary gland shall be specially influenced by mercury; the upper part of the small intestine by calomel; the lower by aloes, &c. &c. Its exercise is continuous, involuntary, known only by its results, and is more marked as we descend in the scale of animal life; whilst animal sensibility is the contrary. *Secondly*. *Insensible organic contractility* is the faculty possessed by every living part, of moving in an

1 Nouveaux Elémens de la Science de l'Homme, Paris, 1806.

2 Institutiones Physiologicæ, Gotting., 1786; or Elliotson's translation.

3 Principes de Physiologie, 2de édit., Paris, 1806.

4 Anatomie Générale, tom. i.; and Recherches Physiologiques sur la Vie et la Mort, Paris, 1800.

imperceptible manner, in consequence of an impression immediately received, without either the mind having consciousness of the motion, the will participating, or the brain in any manner directing it. We have an example of this in the action of the stomach during digestion; and of every part of the body on the blood sent to it for its nutrition. Bichat applied the term *insensible organic contractility* to this property, for the following reasons:—*contractility*, because contraction is the kind of motion which constitutes it; *organic*, because it is common to all living beings; and *insensible*, because the brain has no consciousness of it. Like organic sensibility, it is modified in each organ. Its exercise is likewise continuous and involuntary; and it also exhibits itself more intensely as we descend the scale of beings. It always co-exists with organic sensibility. *Thirdly. Sensible organic contractility* is the same motive faculty as the last, with this difference, that the movements induced by it fall under the senses, and are recognised independently of their results. This property is likewise modified in each organ; its exercise is also involuntary, and it only differs from the last in degree,—the movement that constitutes it being apparent. Thus, the heart contracts independently of the will, but its motions are not imperceptible, as in the cases which belong to the second vital property—insensible organic contractility. *Fourthly. Animal sensibility* is the property possessed by certain organs of transmitting to the mind, through the medium of the brain, the consciousness of impressions, which they have received. It is sensibility in the restricted acceptation of Haller. The epithet *animal* was given to it by Bichat, to distinguish it from the other variety of sensibility, which belongs to all organized bodies, whilst this is exclusively possessed by animals. The whole of the attributes of this property have been detailed at much length in the first volume of this work. *Fifthly.* Bichat admitted a fifth vital property, under the name *animal contractility*, which comprised voluntary muscular contraction;—treated of elsewhere in this work, as one of the functions of the body. It differs from organic contractility in its exciting causes not being seated in the organ in which it is developed,—that is, in the muscles,—but in the brain; and, moreover, whilst other varieties of contractility are irresistibly connected with, and proportioned to, the kind of sensibility correspondent to them, such is not the case with animal sensibility, and its play is never continuous.

From the distinction we have endeavoured to draw between the fundamental vital properties and the functions, it will be obvious that the ingenious division of Bichat is susceptible of farther curtailment by analysis. A vital property must be one possessed by all living bodies; it is fundamental in the tissues, and differs according to the precise structure of the tissue. It is found in the vegetable as well as in the animal. Neither of the two last properties of Bichat, however, corresponds with this definition. They do not exist in the vegetable. They require not only a nervous system, but a brain, that can conceive and will. They are both, indeed, complicated functions, and, as such, have been considered at great length elsewhere. By ultimate analysis, therefore, the five vital properties of Bichat may be reduced to two,—*sensibility* and *motility*. Perhaps we ought to rest satisfied with the

admission, that every primary tissue is capable of being acted upon by appropriate stimuli or is *sensible;* and that it possesses the additional property of *moving* in consequence of such impression. Physiologists have, however, attempted to simplify the subject still farther, and to reduce the vital properties to one only. Such is the view of M. Broussais, who considers *contractility* to be the fundamental vital property of all the tissues. Adelon considers, that *sensibility*, which must carry with it the idea of motion, and is the active, motive faculty of living matter, is the only living property that should be admitted. The term *sensibility* is, however, unfortunate, in consequence of its conveying the notion of mental perception, and of such acceptation having been received into physiology to designate a function. It has, consequently, been proposed to substitute the term *excitability*, *incitability* or *irritability*, but with the same signification. Rudolphi[1] prefers *incitability*, (Erregbarkeit,) as not liable to the objection that may be urged against the others, of having been employed in other significations. This incitability differs in the different organs and tissues; in the muscles he terms it *irritability* (Muskelkraft, Reizbarkeit); in the nerves, *sensibility* (Nervenkraft, Empfindlichkeit); and by some physiologists, in the membranous parts, it is called *contractility* (Spannkraft, Zusammenziehungskraft).

Such are the phenomena that indicate the existence of a vital force, and such the laws by which it seems to be governed. By certain physiologists it is considered to influence solids only: by others, it has been considered to reside in the fluids also, and especially in the blood. The notion of the vitality of this fluid was espoused by John Hunter,[2] and to him we are indebted for many of the facts and arguments brought forward in its favour, which have impelled the generality of modern physiologists to admit its existence. The analogy of the egg had demonstrated that life is not restricted to substances which are solid and visibly organized. The fresh egg, like other living bodies, possesses the ordinary counteracting powers communicated by vitality, and resists those agents that act on the dead egg as on other animal substances deprived of the living influence. The fresh egg may be exposed for weeks, with impunity, to a degree of heat that would inevitably occasion the putrefaction of the dead egg. During the time of incubation, the egg of the hen is kept for three weeks at a heat of 105°; yet when the chick is hatched, the remaining yolk is perfectly sweet. The power of resisting cold is equally great. Dr. Hunter performed several experiments, which show the influence of the vital force in resisting cold, and of cold in diminishing the energy of the force. He exposed an egg to the temperature of 17° and of 15° of Fahrenheit, and found that it took about half an hour to freeze. When thawed, and again exposed to a temperature of 25°, it was frozen in one-half the time. He then put a fresh egg, and one that had previously been frozen and again thawed, into a cold mixture at 15°; the dead egg was frozen twenty-five minutes sooner than the fresh.[3] These experiments led to the legitimate inference, that the

[1] Grundriss der Physiologie, 1er Band., s. 247, Berlin, 1821.
[2] Treatise on the Blood, &c., p. i., ch. i.
[3] Philosoph. Transact., 1778, pp. 29, 30.

egg possessed the force of life, and, although fluid, must have enjoyed the properties which we have described to be characteristic of vitality, —of being acted upon by an appropriate irritant, and of moving responsive to the irritation. Similar results to those obtained with the egg followed analogous experiments with the blood. On ascertaining the degree of cold, and the length of time necessary to freeze blood taken immediately from the vessel, he found that, as in the egg, a much shorter period, and a much less degree of cold, were requisite to freeze blood that had been previously frozen and thawed, than blood recently taken from the vessel. The inference deduced from this was, that the vitality of recent blood being comparatively unimpaired, it was enabled to resist cold longer than blood whose vital energy had already been partly exhausted by previous exposure. It would appear, however, that the vital force in fish can resist the action of frost. Those that were caught by Captain Franklin's party in Winter Lake froze as they were taken out of the nets, and became in a short time a solid mass of ice; yet when thawed they were alive.[1]

The fluidity of the blood whilst circulating in the vessels has been regarded as an additional evidence of its vitality. It is obvious, that such fluidity is indispensable, seeing that it has to circulate through the minute vessels of the capillary system, and that the slightest coagulum forming in them would lead to morbid derangement. Yet the blood is, by its constitution, peculiarly liable to become solid, and whenever it is removed from its vessels it coagulates. This is not owing simply to the cessation of circulation, for if it be kept at the same temperature as in the living body, and be made to circulate with equal rapidity through a dead tube, it equally becomes solid. The cause, consequently, that maintains its fluidity, is the vital agency; or, as J. Müller remarks, the proper combination of its elements is maintained so long only as it is under the influence of living surfaces,—that is, of the vessels. The experiments of Schröder van der Kolk[2] show, that coagulation takes place with extraordinary rapidity after the brain and spinal marrow have been broken down; even in a few minutes after the operation, coagula were found in the great vessels. Mayer observed, that after the application of a ligature to the pneumogastric nerve the blood coagulated in the vessels, and death was produced. Sir Astley Cooper, on repeating the experiment, found, that the conversion of venous into arterial blood in the lungs was prevented. Of four experiments, however, which were performed under the direction of J. Müller,[3]—two on dogs and two on rabbits,—although the animals were examined immediately after death, which resulted from the ligature of the pneumogastrics, in two cases only was a small coagulum, of the size of a pea, discovered in the left side of the heart, and none in the pulmonary vessels. Another argument in favour of the vitality of the blood is drawn from the facts connected with its coagulation,—facts which show that the process is but little influenced by physical agents, and which

[1] See page 219 of this volume.

[2] Comment. de Sanguin. Coagulat., Groning., 1820; and Diss. sist. Sanguin. Coagulat., Groning., 1820, cited in Müller, Handbuch u. s. w., Baly's translation, p. 97, Lond., 1838.

[3] Op. cit., p. 98.

have induced M. Magendie[1] to infer, with many other physiologists, who are but little disposed to invoke the vital agency, "that the coagulation of the blood cannot be ascribed to any physical influence, but must be esteemed essentially vital, and as affording a demonstrative proof, that the blood is endowed with life." It has, indeed, been attempted to show, that there are certain phenomena, which demonstrate that the vitality of this fluid increases or diminishes with the vitality of other parts of the body. When blood is drawn from a vessel it does not instantly coagulate or die; and, by observing the length of time consumed in the process, it has been thought that we might, in some measure, be able to estimate the degree of vital energy it possesses. In diseases where the vital action is exalted,—as in inflammation,—the blood is found to coagulate more slowly than in a state of health, and the coagulation itself is more perfect, whilst in those that are dependent upon a diminution of the vital energy, the opposite is the fact; because, in the first case, it is presumed, the blood possesses the vital force in a higher degree than natural, and consequently resists, for a longer period, the influence of the physical agents to which it is exposed; whilst, in the second case, it possesses the vital force to a less degree than natural, and therefore yields sooner to the influence of those agents, —the coagulation, in all instances, being analogous to the rigidity of the muscles which takes place after dissolution, and has been conceived to indicate the final cessation of vitality or the last act of life.[2]

The *buffy coat* or *inflammatory crust* of the blood, called, also, *corium phlogisticum* and *crusta pleuretica*—the nature of which has been investigated before (vol. ii. p. 123),—is a circumstance connected with the blood's presumed life, that has been invoked by the supporters of this view of the subject. These terms are applied to an appearance of the crassamentum, which is dependent upon its upper portion containing no red particles, but exhibiting a layer of a buff-coloured coriaceous substance lying at the top, owing to the red corpuscles, during coagulation, sinking to the lower portion of the clot, before coagulation is completed; hence, the colourless state of the upper surface. At the same time, the whole of the coagulated portion is generally much firmer than usual. The red corpuscles, in such case, have time to subside before the coagulation is complete, which takes place more slowly than in health; which is conceived to be owing to the blood's possessing a higher degree of vitality,—a view confirmed by some experiments of Mr. Thackrah.[3] These consisted in receiving blood, taken from the vessels of a living animal in a full and uninterrupted stream, into different cups, and noting the time at which coagulation commenced in each. Blood, for example, was taken from a horse at four periods, about a minute and a half being allowed to intervene between the filling of each cup. In the first cup, coagulation began in eleven minutes and ten seconds; in the second cup, in ten minutes and four

[1] Précis de Physiologie, 2de édit., ii. 234, Paris, 1825.

[2] See, on the Evidences of the Life of the Blood, from its self-motion, p. 173 of this volume.

[3] An Inquiry into the Nature and Properties of the Blood, in Health and in Disease, Lond., 1819.

seconds; in the third cup, in nine minutes and thirty-five seconds; and in the fourth cup, in three minutes and twenty seconds. In another experiment, blood was drawn into three separate cups from the veins of a slaughtered ox, the first of which was filled in the first flow; the second, about three minutes afterwards; and the third, a short time before the death of the animal. Coagulation commenced, in the first cup, in two minutes and thirty seconds; in the second, in one minute and thirty-five seconds; and in the third, in one minute and ten seconds. In a similar experiment, it commenced in the first cup, in two minutes and ten seconds; in the second, in one minute and forty-five seconds; and in the third, in thirty-five seconds. Similar phenomena are found to occur in the human subject. Blood, to the amount of about a pint and a half, was taken from the arm of a female labouring under fever. A portion of this, received into a cup on its first effusion, remained fluid seven minutes; a similar quantity, taken immediately before tying up the arm, was coagulated in three minutes and thirty seconds. Of blood, taken as in the last experiment from the arm of a man, the first portion began to coagulate in seven minutes; the last in four. It has been conceived, that the vitality of the system, and with it that of the blood, being diminished, by each successive abstraction, it coagulated or died sooner and sooner in proportion as it was previously more and more enfeebled. It is proper to observe, however, that the blood may remain fluid in the vessels, and coagulate when removed from them, long after the death of the body. In a case observed by the author, it flowed freely from the vessels of the brain and coagulated fifteen hours after the total cessation of respiration and circulation;[1] and many such cases have been observed by others.[2] They would seem to show, that the phenomenon of coagulation is wholly physical in its nature, and not the last act of its vitality, as is held by some.[3] It is affirmed by M. Buisson,[4] that the same fact has been observed in regard to the chyle. In one case it was fluid in a man twenty-four hours after death, but soon coagulated after its escape from the vessels. "Mr. Hunter"—says Mr. Gulliver[5]—"conceiving coagulation to be an act of life, maintained that the blood coagulates by virtue of its living principle. If we admit this hypothesis, we must also admit that we can pickle the life; that it is preserved after repeated freezing and thawing; and, as Dr. Davy remarks, that the blood may remain alive many hours after the death of the body, when the muscular fibre has lost its irritability, the limbs have stiffened, and even partial decomposition has begun. Besides, a mixture of two varieties of per-

[1] Proceedings of the American Philosophical Society, for May, June, and July, 1840, p. 216; and Amer. Med. Intelligencer, Aug. 1, 1840.

[2] The fact was repeatedly noticed by Professor S. Jackson in the bodies of those who died in Philadelphia of the yellow fever of 1820. See J. Davy, Researches, Physiological and Anatomical, ii. 190, Lond., 1839; or Dunglison's Amer. Med. Lib. edit., Philad., 1840. A case has been given by Dr. Polli, in which the blood did not coagulate completely till fifteen days after it was drawn. Gazette Medica di Milano, 20 Gennaio, 1844, cited by Mr. Paget, in Brit. and For. Med. Rev., Jan., 1845, p. 253.

[3] Carpenter, Principles of Human Physiology, 2d edit., p. 516, Lond., 1844.

[4] Gazette Médicale de Paris, 29 Juin, 3 and 17 Août, &c., 1844.

[5] Note to Hewson's works, Sydenham Society edit., p. 21, Lond., 1846.

fectly clear serum will coagulate spontaneously, as I have witnessed upon filtering them four days after they were drawn from the living human body; and M. Denis states, that fibrin may be dried and powdered, and yet possess the power of self-coagulation when dissolved in a neutral salt, and diluted with water."

The late Professor Harrison, of New Orleans,[1] who was properly chary in ascribing to vital influence what may admit of a physical or chemical explanation, expresses the opinion "that we must expect from chemistry the solution of the mystery of the change of form that takes place as well during the coagulation of the blood as in other cases, in the existing state of knowledge inexplicable; and he instances the spontaneous change of form from fluid to solid that takes place in cyanic acid from no known cause; as well as in chloral and aldehyde." The change of form that occurs in the last substance, he considers to be "even more singular than that which occurs in the fibrin of the blood, and equally inexplicable in the present state of science." "As well" —he adds—"might we invent some *principle* to account for the transformations of aldehyde as for those of fibrin."

It is manifest, then, that if it be granted that some of the above and other arguments lead to a belief in the vitality of the blood, they are equally favourable,—many of them at least,—to the vitality of the chyle, which—we have seen—closely resembles the blood in its properties, except in that of coloration; and if we admit the blood to be possessed of life, a question arises, respecting the part at which the nutritive substances, taken into the system, become converted into the nature of the being they are destined to nourish, and receive the vital force. This must be either through the admixture of the fluids poured out from the supra-diaphragmatic portion of the alimentary canal, or from those of the stomach or small intestine; or owing to the mysterious and inappreciable agency of the chyliferous radicles themselves, which separate the same fluid, chyle, from every substance, that may be submitted to their action. A reference to what has been said on these topics, under the heads of DIGESTION and ABSORPTION, would lead to the opinion, that no vitalizing influence is exerted on the food in the stomach and intestines; and, therefore, that the infusion of vitality—if the expression may be allowed—would have to take place in the chyliferous vessels. As to the mode in which the blood becomes vitalized—if possessed of vitality—great doubt must necessarily exist. The general opinion, perhaps, is, that it is made so by the organic nerves distributed to the inner coats of the vessels; and this idea was considered to be confirmed by an experiment of the late Mr. Thackrah, which showed, that blood, received into a dead vessel, is always more speedily coagulated than when it is retained by ligature in a living vessel; whence he inferred, that the vitality of the vessels affects the blood; and retards its coagulation. Mr. Thackrah denies, indeed, the life of the blood, and ascribes all the evidences which it exhibits of life, to the influence exerted by the living vessels on their contents.

On the whole, then, we are led to the conclusion, that the doctrine,

[1] New Orleans Medical and Surgical Journal, July, 1847, p. 46.

which maintains, that the blood is a living fluid is by no means established, and that facts and arguments are more in favour of the view, that in the bloodvessels fluid is contained, and distributed over the body, which serves as the pabulum from which every part of the organism is formed; but that the real plastic or organizing power is seated in the cells, which constitute the various tissues; and it is necessary for appropriate materials to leave the vessels, and come in contact with them in order that organized tissue shall result from their elaborating agency.

To employ the language of Dr. Barclay,[1] all that we seem to know regarding the vital force or principle is—"that all the organisms of animals and plants are formed out of fluids, and that in a certain species of fluid, secreted from the parent, and afterwards enclosed in a very thin and transparent vesicle, there is a living, organizing principle, which also acts upon the fluids in a way which we know not, forming out of it a regularly organized system of solids and forming not only the rudiments of that system, but causing it afterwards to be nourished, and to grow, through the medium of fluids, which are moved and distributed under the influence of this organizing animating principle." Our knowledge being limited to this category, we are compelled to study life in its results or manifestations. These, as we have seen, constitute the Science of *Life*, *Biology* or *Physiology*.

CHAPTER VI.

DEATH.

It has wisely entered into the views of Providence, that the existence of all organized bodies should be temporary; yet we find considerable difference amongst them in this respect. Whilst some of the lower classes of animals and vegetables are no sooner ushered into being than a process of decay appears to commence; others require the lapse of ages for their developements and declensions; and, as a general rule, those, in which the attainment of growth has been slow, have the period of decrease proportionably postponed; whilst, where maturity has been rapidly attained, decay as rapidly supervenes.

It has been elsewhere shown, that each part of the body, as regards the cells that compose it, may be considered to have a life of its own, —a cell life: hence, a minute part may die and be reproduced without the general life of the individual suffering; and in certain of the lower animals, so little is the organism affected by injuries of a part, that when the animal is cut in pieces, each piece may undergo a distinct developement, so as to form as many separate beings. In the higher animals, however, this is not the case. In them, the death and reproduction of every part of the frame are taking place in the function of nutrition; and it is only when organs, that are intimately associated with each other, and whose association is essential to the life of the

[1] Inquiry into Life and Organization, p. 527, Edinb., 1822.

whole, have their functions interrupted, that the cessation of other functions, and general death, follow. The death that takes place in minute parts has been called *molecular;* that of the whole body *somatic.*

The ages of man are numerous and protracted. For a time, the parts of the frame concerned in his developement unceasingly deposit the necessary particles, by a process as beautiful and as systematic as it is mysterious; until ultimately the growth peculiar to the species and the individual is attained. At this point, the preponderance, that previously existed in the action of the exhalants over the absorbents, appears to cease. All is equality; but, ere long, the exhalants flag in their wonted activity; the fluids decrease in quantity; the solids become more rigid; and all those changes supervene, which we have described as characterizing the decline of life, and the approach of the phenomenon that has now to be considered.

Death is the necessary, total, and permanent cessation of those functions, by which the presence of life is characterized. This cessation may happen at all ages from accident or disease; a few only cease gradually to live through the effects of age alone. Hence, a distinction has been made into that kind of death, which is produced by the gradual wear and tear of the organs, and that which cuts off the being prematurely from existence. The former has been termed, by some physiologists, *senile* or *natural;* the latter *accidental.* These differ considerably in their physiology; and will, therefore, require a distinct consideration.

1. DEATH FROM OLD AGE.

The *natural period of life* is different in different individuals. It varies according to numerous appreciable and inappreciable circumstances:—the original constitution of the individual; habits of life; the locality in which he may reside, &c. Whilst some countries are remarkable for the longevity of their inhabitants; others surprise us by the short period allotted for the natural duration of life. Blumenbach asserts, that by an accurate examination of numerous bills of mortality, he ascertained the fact, that a considerable proportion of Europeans reach their 84th year, but that few exceed it; whilst, according to M. Foderé,[1] in the insalubrious region of Brenne, in France, nature begins to retrograde at from 20 to 30; and 50 years is the usual term of existence. Haller[2] noted one thousand cases of centenarians; sixty-two of from 110 to 120 years; twenty-nine of from 120 to 130; and fifteen who had attained from 130 to 140 years. Beyond this advanced age examples of longevity are much more rare, and less sufficiently attested; yet we have some well-authenticated cases of the kind. Thomas Parr, who died in 1635, married at the age of 120, retained his vigour till 140, and died at the age of 152, from plethora—it was supposed—induced by change of diet. Harvey dissected him and found no appearance of decay in any organ.[3] Henry Jenkins, who died in Yorkshire, in 1670, is an authentic instance of the greatest longevity on record. He lived 169 years.

[1] Traité de Médecine Légale et d'Hygiène Publique, tom. v p. 537, Paris, 1813.
[2] Element. Physiol., xxx. 3.
[3] Philos. Transact., vol. iii. 1699.

The following list of instances of very advanced age has been given.[1]

	Lived.		Age.
Apollonius of Tyana,	A. D. 99	-	130
St. Patrick,	491	-	122
Attila,	500	-	124
Llywarch Hên,	500	-	150
St. Coemgene,	618	-	120
Piastus, King of Poland,	861	-	120
Thomas Parr,	1635	-	152
Henry Jenkins,	1670	-	169
Countess of Desmond,	1612	-	145
Thomas Damme,	1648	-	154
Peter Torton,	1724	-	185
Margaret Patten,	1739	-	137
John Roven and Wife,	1741	-	172 and 164
St. Mongah or Kentigen,	1781	-	185

It would not seem that the natural period of life has differed much in postdiluvian periods. The Psalmist writes:—

"The days of our years are threescore years and ten; and if by reason of strength they be fourscore years, yet is their strength labour and sorrow, for it is soon cut off, and we fly away."[2]

And when Barzillai excused himself for not visiting the royal palace at Jerusalem, he observed to the king:—

"I am this day fourscore years old, and can I discern between good and evil? can thy servant taste what I eat or what I drink? can I hear any more the voice of singing men or singing women? wherefore then should thy servant be yet a burden unto my lord the king?"[3]

The census of the United States has strikingly exhibited the influence of races on longevity in the same country. In 1830, according to Professor Tucker,[4] the proportion of whites over 100 years of age, was 1 in 19,529; of free coloured, 1 in 487; and of slaves, 1 in 1410. The census of 1840 confirms this immense difference,—the whites over 100 were in the proportion of 1 in 17,938; the free coloured of 1 in 597; and the slaves of 1 in 1,866. It is affirmed by Tschudi,[5] that the Peruvian Indians are remarkable for longevity, although they frequently shorten their lives by the intemperate use of strong drinks. Instances, he says, are not rare of their living to 120 or 130 years of age, retaining full possession of their bodily and mental powers.

It is not easy to indicate the character of organization most conducive to longevity and to health. Much must depend on the habits of the individual, and the degree of toil and exposure to which he has been subjected; and this may partly, if not wholly, account for the greater longevity of women, which in England, as well as in this country,—as far as observation has been made,—is decided. Of four-

1 Prichard, Researches into the Physical History of Mankind, 2d edit., i. 421, London, 1836.

2 Psalm xc.

3 2 Samuel, xix. 35.

4 Progress of the United States in Population and Wealth in Fifty Years, as exhibited by the Decennial Census, p. 72, New York, 1843.

5 Travels in Peru during the years 1838–1842, translated by Thomasina Ross, p. 339, New York, 1847.

teen who lived beyond one hundred years in the Philadelphia Hospital, during a period of twelve years,[1] but five were men; and the only two who exceeded 110 were women, one of whom reached her 119th year, and died of cholera in 1832.

It has been generally considered, that the proportion of deaths to the population in any community may be regarded as an exponent of the *average duration of life* in that community;—that if, for example, in Philadelphia 1 in 45 dies yearly, the average age of all who die will be 45. So far as the estimates made of the number of people before any census was taken may be depended upon, it would appear, according to Mr. Chadwick,[2] that the ratio of deaths in London to the population was, at the commencement of the last century, 1 in 20. At the time the first census was taken—in 1801—the ratio, within the bills of mortality, was 1 in 39. In 1843, it appeared to be 1 in 40. Having had the average ages of death within the bills of mortality calculated from the earliest to the later published returns, he found them, as far as they could be made out from the returns, which are only given in quinquennial and decennial periods, to be as follows:

	Average age.
22 years, from 1728 to 1749, - - - -	25 years, 1 month.
25 years, from 1750 to 1774, - - - -	25 " 6 "
25 years, from 1775 to 1799, - - - -	26 " 0 "
25 years, from 1800 to 1825, - - - -	29 " 0 "
6 years, from 1825 to 1830, - - - -	29 " 10 "

Whilst, consequently, it would appear, from the proportionate number of deaths to the population, that the average duration of life had doubled during the last century, the returns of the average ages show, that it had only increased about one-fifth. In one year the mortality may be greater amongst children, in another amongst the aged; so that whilst the proportion of deaths to the population may be the same, the average of the ages at which death occurs may differ materially.[3]

Generally, the aged individual sinks silently to death, totally unconscious of all that surrounds him, in the manner described under Decrepitude. At other times, he preserves his sensorial powers to the last, and may be capable of locomotion; until, owing to oppression or disturbance of action of one or other of the vital functions during sleep, it becomes the sleep of death,—the elasticity of the organs being insufficient to throw off the deranging influence and resume their functions. At other times, a slight febrile irritation is the prelude to dissolution.

The great characteristic of this kind of death—as pointed out by Bichat in one of the best of his excellent productions[4]—is, that animal life terminates long before organic life. Death takes place in detail,—the animal functions, which connect the aged with the objects around him being annihilated long before those that are concerned in his

[1] Tabb, American Journal of the Medical Sciences, Oct. 1844, p. 373.
[2] Report on the Practice of Interment in Towns, p. 241, London, 1843.
[3] Fifth Annual Report of the Registrar General, &c., London, 1843.
[4] Recherches Physiologiques sur la Vie et la Mort, Paris, 1800.

nutrition. Death, in other words, takes place from the circumference towards the centre, whilst in accidental or premature death, the annihilation of the functions begins in the centre and extends to the circumference. As vitality gradually recedes in the aged from the exterior, one of the great centres of vitality—brain, heart, or lungs—stops for an instant. The powers are insufficient to restore the action, and total death necessarily ensues.

It has been an interesting topic with physiologists to determine the cause of death thus naturally occurring. Opinions have varied, but such causes as affect the three great vital functions seem to be most entitled to consideration. These have been supposed to be:—*First*, ossification of the arteries, occasioning an obstacle to the free circulation of blood in the parts; *Secondly*, ossification of the cartilages of the ribs, and diminution of the capillary system of the lungs, preventing sanguification;—and *Thirdly*, shrivelling and gradual induration of the nervous system, rendering it ultimately unfit for innervation, &c. These are the physical circumstances or changes, that may give occasion to the final cessation of the vital phenomena; but, after all, the difficulty remains,—and it is insolvable,—to explain the cause why these changes themselves occur in the organs essential to vitality. We say it is insolvable, for, until we have learned the nature of life, which seems far beyond our comprehension in the present state of knowledge, it is obviously impracticable to understand the phenomena that arise from its gradual declension and final extinction. This kind of death, produced by the gradual declension of the powers of life, is regarded by Dr. W. Philip[1] as only the last sleep, characterized by no peculiarity, in which the powers, partly from their own decay, and partly from the lessened sensibility increasing the difficulty of restoring the sensitive system, become incapable of the office, and the individual, therefore, wakes no more. We have before remarked, that there appears to us to be a marked difference between sleep and death, although they may trend closely on the confines of each other. It is not common, however, for death to occur in this quiet and gradual manner. Man is liable to numerous diseases from the earliest to the latest period of existence, many of which are of a fatal character. It was admitted by Sydenham, whose estimate cannot be regarded as more than an approximation, that two-thirds of mankind die of acute diseases; and that of the remaining one-third, two-thirds, or two-ninths of the whole die of consumption, leaving, consequently, only one-ninth to die from other chronic maladies, and from pure old age. How small, then, must be the number of those who expire from decrepitude simply!

2. ACCIDENTAL DEATH.

This term has been used by many physiologists to include all kinds of death that befall man in the course of his career, and before the natural term; the cause consisting in some accidental organic lesion, which arrests the vital movements before they would cease of them-

[1] Philosophical Transactions for 1834; and an Inquiry into the Nature of Sleep and Death, p. 166, London, 1834.

selves. This kind of death differs essentially from that which we have been considering. The individual is here, perhaps, in the full possession of all his faculties; his organs have been previously, to all appearance, in the most favourable condition for the prolongation of life; and his death, instead of being natural, and unperceived in its approaches by the individual himself, is usually forced and violent.

Every form of sudden death commences by the interruption of one of the three great vital acts, circulation, respiration, or innervation. One of these functions ceases first, and the others die in succession, or the lethiferous influence, as in poisons acting through the blood—*necræmia*—may affect them all in succession or simultaneously. Each will demand a few remarks.

a. *Death beginning in the Heart.*—When—owing to fatal syncope, to wounds of the heart or great vessels, or to the rupture of an aneurism—the heart is struck with death, the cessation of the functions is speedy. Sensation and motion are lost; respiration is arrested, and death occurs,—if the cause of the cessation of the heart's action be suddenly and sufficiently applied,—almost instantaneously. The order in which death takes place in the different organs is as follows:—The heart failing to propel its blood, the encephalon and gray matter of the medulla spinalis no longer receive the necessary impulse for the continuance of their functions; they therefore cease to act; the consequence of this is the death of all those organs that receive their nervous influence from them; all voluntary motion is annihilated, as well as the action of the respiratory and other reflex muscles; the mechanical phenomena of respiration are, consequently, arrested; and air is no longer received into the chest. From this cause, then, the chemical phenomena of respiration would cease, were they not previously rendered unnecessary by the cessation of the heart's action. The phenomena of nutrition, secretion, and calorification,—functions connected with the intermediate system of vessels,—yield last. Dr. C. J. B. Williams[1] divides death beginning at the heart into two modes—*sudden*, as in syncope, and *gradual*, as in asthenia. In the latter case, however, where the cessation of action of the different organs occurs from want of power, as in exhausting diseases, it is not easy to say, in all cases, which is the first link in the chain of fatal phenomena.

b. *Death beginning in the Nervous Centres.*—This may occur in the encephalon, or in the gray matter of the medulla spinalis. In the former case, owing to the loss of innervation,—as in severe injury done to the head, or the worst attacks of apoplexy,—the sensorial functions first cease, and the individual lies deprived of sensation, volition, and mental and moral manifestation—*coma:*—respiration continues, owing to the reflex nervous system being secondarily affected only: but it becomes progressively more irregular and laborious, and ultimately ceases. The order of death is here as follows:—the interruption of the brain's action destroys first that of the voluntary, and secondly that of the mixed muscles; the mechanical phenomena of respiration therefore cease, and then the chemical. This is followed by cessation of the heart's action,

[1] Principles of Medicine, Amer. edit., by Dr. Clymer, p. 363, Philad., 1844.

owing to the united loss of nervous influx from the brain, and the want of a due supply of blood. To the cessation of the heart's action succeeds the loss of the general circulation; and lastly, that of the functions of nutrition, secretion, and calorification. It rarely perhaps happens, that death arises from sudden arrest of action of the true spinal or reflex system. In such case, all the muscles, that are animated by this portion of the nervous system, would become at once paralysed.

c. *Death beginning in the Lungs.—Death by Asphyxia* or *Apnœa.*—The action of the lungs may be destroyed in two ways: either the mechanical phenomena of respiration may first cease, as in hanging, strangulation, &c., when air is prevented from reaching the lungs; or the chemical phenomena may be first arrested, as when air is breathed, which does not contain oxygen, but yet can be respired for a time. In the first case, the order of death is as follows:—the mechanical phenomena cease; to this succeeds cessation of the chemical phenomena, owing to the supply of air being cut off; the blood, not experiencing the necessary conversion in the lungs, soon stagnates in the pulmonary capillaries: for a time, however, the heart continues to beat, owing to the aeration effected by the residuary air in the minute bronchial ramifications; but this soon ceases in consequence of defective supply of blood; the nervous centres die, and other parts in succession. When the chemical phenomena cease first, the suspension of the action of the nervous centres, for the cause already assigned, follows; and the mechanical phenomena are not arrested, until the nervous influx is cut off by the death of its organ.

Dr. Williams adds another chief variety of the modes of death,—*Death beginning in the Blood—Necræmia.* In this variety, owing to poisonous influences, as in typhus and other malignant fevers, the life or characters of the blood become annihilated suddenly, or progressively. Death, however, in this case, must still be occasioned by the lethiferous influence exerted by the blood on one or more of the three great vital functions.

The immediate phenomena of death and the order of their succession are easily understood, when one of the great centres of vitality is suddenly destroyed either from accident or disease; but when death does not follow immediately, and time is allowed for a series of morbid phenomena to be established, the problem becomes much more complicated. Some organ or structure is first deranged; and, owing to the intimate connexion, which, as we have elsewhere seen, exists between the various functions, general derangement or irritation follows, and the individual dies, worn out by such irritation, but without our being able to understand on which of the great centres that dispense vitality the malign influence has been exerted, or whether it may not have affected all equally. In inflammation of the brain, heart, or lungs, we may presume, that the functions of these organs have been respectively annihilated by the diseased action; and that, as such functions are essential to the existence of vitality, death may arise in the manner already described. But we frequently find the bowels, or the peritoneum lining the interior of the abdomen, affected with inflammation; and the case, if neglected, is as surely attended with fatal consequences as the same morbid affec-

tion of organs termed vital; and this in a space of time so short, as not to enable us to understand the nature or mode of action of the lethiferous agent; but that it must exert its influence on one or more of the great centres of vitality is manifest. In many cases, the heart seems to yield first, not suddenly but gradually; the brain, failing to receive its due impulse, becomes progressively unfit for transmitting the nervous influence to the muscles; insensibility gradually supervenes, until it has attained such an extent, that no nervous influence is sent to the respiratory muscles, when cessation of their action naturally ensues. Of the nature, however, of the morbid condition of the heart, thus induced by disease, we are totally ignorant. It is fashionable to say, that death is produced by irritation, but this is merely concealing our deficiency of knowledge under a term, the explanation of the agency of which comprises the whole difficulty. M. Adelon[1] thinks, that the brain generally gives way first in these cases; in consequence of which the respiration is disturbed; the lung becomes engorged; breathing more and more difficult, and death occurs as in a case of gradual asphyxia. There is something extremely obscure in these cases. It often happens, that the intellectual manifestations and nervous distribution to the muscles of voluntary motion are executed, even vigorously, until a short time prior to dissolution, whilst the feeble, irregular, and intermittent beat of the heart may indicate how greatly its irritability is morbidly implicated.

These remarks are chiefly applicable to death as it arises from the numerous acute affections that are so fatal to mankind; but it may occur, also, from those, that persist for a great length of time, and destroy after months or years of morbid irritation, as in cases of calculi of the bladder, engorgements of the viscera, &c. In these cases, likewise, death must ultimately result from the destruction of one or other of the vital functions,—respiration, circulation, or innervation; but in a manner so gradual, that it takes place nearly in the same way as in old age; except that, in all cases, it proceeds from the centre to the circumference, the great internal functions first ceasing, and afterwards their dependencies,—a difference which explains why we are justified in attempting means of resuscitation in sudden death, whilst it would be the height of absurdity to have recourse to them where,

> "Like a clock worn out with eating time,
> The wheels of weary life at last stand still."

The renovation could only be effected by the substitution of new, for the worn out, machinery.

It has been already shown (vol. ii. p. 478), that there are certain causes of death, which affect the two sexes in infancy to a different extent; and the same fact is exhibited when the ratio of deaths of male and female is taken at all ages. The following table, from the valuable statistical report now annually made by the direction of the British government, shows this in a striking manner.[2]

[1] Physiologie de l'Homme, 2de édit., iv. 472, Paris, 1829.

[2] Mr. W. Farr, in Third Annual Report of the Registrar General of Births, Marriages, and Deaths in England, p. 72, Lond., 1841.

Causes of Death.	Number of Deaths.			
	1838.		1839.	
	Males.	Females.	Males.	Females.
Cancer - - - -	620	1,828	660	2,031
Hooping-cough - -	4,036	5,071	3,683	4.482
Consumption - - -	27.935	31,090	28,106	31,453
Child-birth - - -		2,811		2,915
Violent deaths - - -	8,359	3,368	8,325	3.307
Hydrocephalus - - -	4,242	3,430	4.313	3,436
Diabetes - - - -	152	55	151	63
Convulsions - - -	14,549	11,498	14,245	11,163
Delirium tremens - -	167	15	184	22
Tetanus - - - -	100	29	102	20
Bronchitis - - -	1.193	874	916	747
Pleurisy - - - -	329	253	342	246
Pneumonia - - -	9,887	8,112	10,000	8,151
Asthma - - - -	3,359	2,386	3,092	2,091
Pericarditis - - -	74	50	83	52
Aneurism - - -	88	31	69	33
Hernia - - - -	318	189	299	175
Fistula - - - -	82	18	81	22
Stone - - - -	282	38	274	25
Cystitis - - - -	103	25	118	20
Nephritis - - - -	113	44	99	32
Gout - - - -	161	46	170	45
Dropsy - - - -	5,170	7,172	5,268	6,983
Intemperance - - -	125	36	178	40
Starvation by want, cold, &c.	126	41	85	45

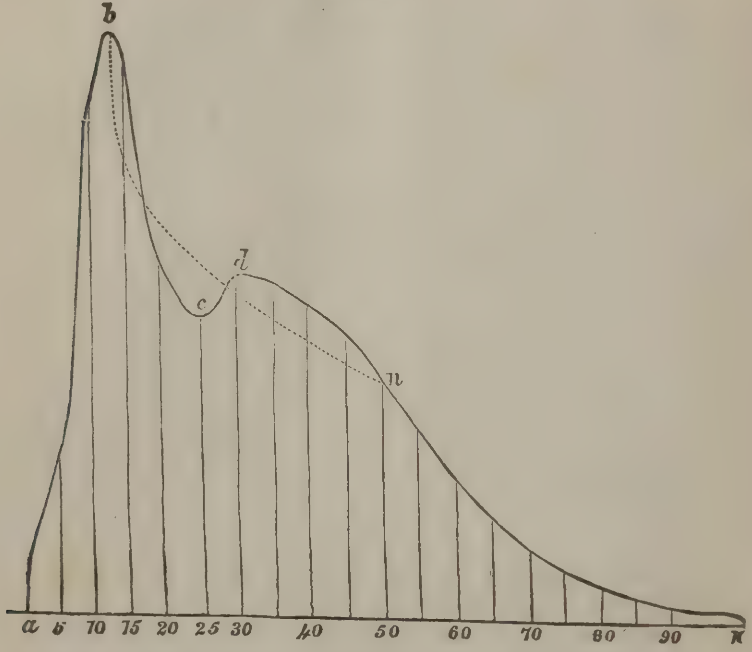
The diagram, Fig. 472, from M. Quetelet,[1] exhibits the relative viability of the two sexes as deduced by him from numerous statistical inquiries. The dotted line represents the viability of the female: the other that of the male. According to this, the maximum of viability is at the age of 14 in both sexes. After puberty, it diminishes more rapidly in the female than in the male. It is also less during the period of childbearing, from the 27th to the 45th year. The age of shortest viability is immediately after birth; that of the longest viability immediately before puberty. The viability of the child after the first month of existence, according to M. Quetelet, is greater than that of the man nearly 100 years old. Towards the 75th year, it is scarcely greater than that of the infant about the sixth month after birth.

For some time before dissolution,—both in death from old age and from disease,—the indications of the fatal event become more and more apparent. The speech grows embarrassed; the ideas are incoherent; the hands, if raised by the effort of the will, fall inertly into their former position; the laboured respiration occasions insufficient hæmatosis, and the distress excites an attempt at respiration, which the debility renders nearly ineffectual; distressing yawnings and gaspings occur to remedy the defective pulmonary action, and the whole respiratory system is in forcible and agitated motion,—the teeth, at times, gnashing, and convulsive contractions occurring at the corners of the mouth. The heart

[1] Sur l'Homme, &c., English edit., p. 32, Edinb., 1843.

becomes gradually unable to propel the blood with the necessary force into the arteries, so that the fluid ceases to reach the extremities of the body—the hands, feet, nose, and ears—which grow cold, and a cold

Fig. 472.



Curves indicating the Viability or Existibility of Male and Female at Different Ages. (Quetelet.)

clammy moisture oozes from the vessels. In experiments on animals, the blood is found to be gradually driven no farther than to the feet; then to the groin; afterwards it reaches only to the kidneys, and a kind of reflux occurs through the space along which it had previously been urged forwards. The flux and reflux now reach no farther than the diaphragm, and gradually retreat, until the blood flows back upon the heart itself, which now stops for a time, and then makes an effort to free itself from the contained fluid. The heart's action and respiration are imperfectly performed for a few times at irregular intervals, until at length the contractility of the organ is entirely gone. Respiration ceases by a strong expulsion of air from the chest,—often accompanied by a sigh or a groan, and probably arising in part from the relaxation of the inspiratory muscles, but still more from the elasticity of the cartilages of the ribs. Hence it is that, in common language, *to expire* is synonymous with *to die*. In cases of sudden death, the heart may continue to beat for a while after innervation and respiration have ceased.

For some time immediately preceding dissolution, there is usually a

peculiar mixed expression of countenance,—a compound of apparent mental and corporeal suffering,—which has given occasion to its being called "the *agony*." It is characterized by facial indications, that were first well described by Hippocrates, and from him called *Facies Hippocratica*. The nose is pinched; the eyes are sunken; the temples hollow; the ears cold and retracted; the skin of the forehead is tense; the lips are pendent, relaxed, and cold. The eye, during this condition, especially when dissolution approaches, is fixed and slightly elevated, being kept in that position, according to Sir Charles Bell, by the power of the brain over the voluntary muscles of the eye being lost, and the organ being given up to the action of the oblique, which he considers to be involuntary muscles. The word "agony," applied to this condition, means in many languages a violent contest or strife, but its acceptation has been extended so as to embrace what have been termed the "pangs of death" and any violent pain. This agony of death, however, physiologically speaking, instead of being a state of mental and corporeal turmoil and anguish, is one of insensibility. The hurried and laboured breathing; the peculiar sound on inspiration, and the fixed and turned up eyeball, instead of being evidences of suffering, are now admitted to be signs of the brain having lost all, or almost all, sensibility to impressions. All the indications of mortal strife are such in appearance only; even the convulsive agitations, occasionally perceived, are of the nature of epileptic spasms, which we know to be produced in total insensibility, and to afford no real evidence of corporeal suffering.

Although, from the moment that respiration and circulation permanently cease, the body may be regarded as unquestionably dead, vital properties remain in some of the organs, the presence of which is an evidence that vitality has previously and recently existed. The functions, which persist after the animal has become dead to surrounding objects, are those that belong to the organic class. Absorption is said to have occurred after death, and the beard and hair to have grown. To a certain degree this growth is possible, in parts that are nourished by imbibition; but the apparent elongation of the hair may be owing to the shrinking of the integuments. The rectum is very frequently evacuated after dissolution; and cases have occurred where a child has been born by the contraction of the uterus after the death of the mother. The most marked evidence, however, of the continuance of a vital property after dissolution, is in the case of the muscles, which, as we have mentioned in another place, can be made to contract powerfully on the application of an appropriate stimulus, even for an hour or two after death. Nysten,[1] from his experiments, inferred, that the parts cease to contract in the following order:—the left ventricle, large intestine, small intestine, stomach, bladder, right ventricle, œsophagus, iris, different voluntary muscles, and, lastly, the auricles, particularly the right auricle.

The body cools gradually at the surface, and especially towards the extremities. In many cases, however, instead of gradually cooling, the

[1] Recherches de Physiologie et de Chimie Pathologiques, Paris, 1811.

temperature actually rises. Dr. John Davy[1] had noticed, that after death from fever, the thermometer, placed under the left ventricle of the heart, indicated, in one case, a temperature of 113°; but the temperature before death was not noted, and he was induced to believe, that the elevated temperature was generated before death, and "probably in the same way as the ordinary degree of animal heat, experienced in health, or the extraordinary degree witnessed in febrile diseases." Experiments, however, by Dr. Bennet Dowler,[2] of New Orleans, have satisfactorily shown, that the increased production of heat, which he noticed in yellow fever cases, occurs after the cessation of respiration and circulation, and only ceases with the putrefactive process. In one case, for example, the highest temperature during life was in the axilla, 104°; ten minutes after death it was 109° in the axilla; fifteen minutes afterwards, it was in the thigh 113°; in twenty minutes, the liver gave 112°; in one hour and forty minutes, the heart 109°,—the thigh, in the old incision, 109°; and in three hours after removing all the viscera, a new incision in the thigh gave 110°. It is curious, that the maximum of observed heat after death was in the thigh. The following table by Dr. Dowler exhibits the highest amount of temperature noted in eight different regions in different subjects.

Thigh.	Epigastrium.	Axilla.	Chest.	Heart.	Brain.	Rectum.	Liver.
113°	111°	109°	107°	109°	102°	111°	112°
109	110	109	106·5	106	101	109	109
109	109	108	106	105	101	107	108
109	109	108	106	104	100	107	107
108	109	107	105	104	99	106	106
Mean 109·4	109·6	108·2	106·1	105·6	100·6	108	108·4

It appears from Dr. Davy, Dr. Dowler, and Dr. Benjamin Hensley, jr.,[3] who instituted some observations at the Philadelphia hospital, at the request of the author, that the brain produces less heat after death than the contents of the other splanchnic cavities. The bearing of these phenomena on the explanation of calorification has been noticed elsewhere.

Another remarkable phenomenon, noticed by Dr. Dowler[4] in yellow fever subjects especially, "which are incomparably the best for study," is what he has termed "post-mortem contractility." Numerous experiments were performed by him on bodies, that had been dead from a few minutes to several hours, in which the muscles of the extremities, struck with a cane, billet of wood, the hand, or the side of a hatchet, contracted with sufficient force to move a weight of several pounds, and he found, that if several blows on the same spot followed each other rapidly, there was but one contraction, but they exhausted the contractile function more

[1] Researches, Physiological and Pathological, Amer. edit., p. 328, Philad., 1840.

[2] Medical Examiner, June, 1845, cited from Western Journal of Medicine and Surgery, June and October, 1844.

[3] Medical Examiner, March, 1846, p. 149.

[4] Experimental Researches on the Post-mortem Contractility of the Muscles, with Observations on the Reflex Theory, reprinted from the New York Journal of Medicine, for May, 1846.

than a single blow; "and if the force be greatly augmented the contractility may be killed, almost immediately in the muscle struck, without impairing the action of any other part."

Whilst the refrigeration of the body is going on, the blood remains more or less fluid; and owing to the arteries emptying themselves, by virtue of their elasticity, of their contained blood, it generally accumulates in the venæ cavæ, auricles of the heart, and vessels of the lungs. By virtue of its gravity, it collects also in the most depending parts, occasioning cadaveric hyperæmiæ, suggillations or livid marks, which might be mistaken for bruises inflicted during life; but may generally be distinguished from them by attention. It will be readily understood, that the situation of the blood in the vessels may differ somewhat according to the vital organ which first ceases its functions. If the action of the right heart stops, the lung may be empty; if the lung or left heart ceases, the lung and right side of the heart—with the vessels communicating with it—may be surcharged with blood, whilst the organs of the corporeal circulation may be almost empty. During the progress of refrigeration, and especially soon after death, the muscles are soft and relaxed, so that the limbs fall into the position to which the force of gravity would bring them; the eyes are half open; and, according to a recent writer, M. Rippault[1]—the iris is perfectly flaccid when the globe of the eye is compressed in two opposite directions; and if the person be alive the pupil will retain its circular form notwithstanding the compression; whilst if dead, the aperture becomes irregular and the circular form is lost: the lips and lower jaw are pendant, and the pupil dilated. When the body, however, is cold, the blood is coagulated, and white or yellowish coagula exist, especially in the cavities of the heart, which were at one time supposed to be morbid and termed *polypi.* They take the shape, more or less, of the cavity in which they are found. Lastly, the muscles become firmly contracted, so that no part can be moved without the application of considerable force; and, in this state, they continue until the natural progress towards putrefaction again softens their fibres. This has been regarded by physiologists as arising from the last exertion of that residue of vital power, which the body retains after the period of apparent dissolution. With more propriety, perhaps, the *rigor mortis* may be assigned to physical alterations taking place in the organs, owing to the total loss of those powers, which were previously antagonistic to such changes. It has been attributed, by M. Brück,[2] to the coagulation of the liquids in the interior of the tissues. He considers, that the fibrin of the muscle coagulates, when the muscular fibre is deprived of life. By some, the muscular contraction, which gives occasion to the *rigor mortis*, is held to be of the same kind as that which takes place under the influence of the nervous stimulus, although differing as to its conditions. When very strong, it renders the muscles prominent, as in voluntary contraction; and Dr. Carpenter[3] thinks the comparative observations of Mr. Bowman upon the state of muscular fibre passing into this condition, and upon that which presented various

[1] Cited in London Medical Gazette, May, 1846.
[2] Müller's Archiv., Nov. 1842; cited in Edinb. Med. and Surg. Journ., Oct., 1843, p. 492.
[3] Principles of Human Physiology, 2d edit., p. 324, Lond., 1844.

degrees of contraction from ordinary causes, leave no doubt as to their correspondence. The conditions are certainly, however, very different; for the power of the muscle to contract on the application of appropriate stimuli is lost before the rigor mortis sets in.

It might seem from the previous enumeration of the signs of death, that no difficulty could possibly arise in discriminating between a living and a dead body. Cases have, however, occurred, where such difficulty has been great and perplexing. Many of the signs may exist, and yet the person be merely in a state of suspended animation; and in certain instances it has even been considered advisable to wait for the manifestations of the putrefactive process, before the body should be consigned to the grave. The following case, given by Dr. Gordon Smith,[1] strongly exhibits the embarrassment that may occasionally occur. A stout young man had been subject to epilepsy, which became combined with madness. On this account it was necessary to remove him to a private asylum in the neighbourhood of London, where he died suddenly in a violent epileptic paroxysm. The body was removed to the residence of his friends soon after death, when the necessary preparations for interment were made. On paying attention to the corpse it was found, that the limbs were pliable; that the eye was neither collapsed nor glazed; and that the features retained their full natural appearance as during life. A surgeon, who, for years, had been in the habit of attending him, was sent for; and although he could find no indications of vitality, he prudently recommended, that the interment should not take place until decomposition had begun to manifest itself. In the course of two or three days, appearances still continuing the same, a physician was called in, who concurred in the recommendation that had been given. Fifteen days from the supposed time of his death had elapsed, when Dr. Smith's informant had an opportunity of inspecting the body. At this time, the countenance retained the appearance described, but the eye seemed beginning to sink, and some degree of lividity had commenced on the surface of the abdomen. The joints were still flexible. At this time, a very eminent professor of anatomy viewed the body, and, considering the hesitation that had prevailed to be altogether groundless, he appointed the following day to examine it internally. The head was accordingly opened, and a considerable extravasation of blood was found in the posterior part of the cranium, between the skull and dura mater, and between the membranes and substance of the brain. No serum was detected in the ventricles; but the brain itself was remarkably hard. This was sixteen days after death. On the following day, the body was interred. A clamour now arose amongst the neighbours, that he had been prematurely handed over to the anatomist. The body was exhumed; an inquest was held; and the evidence of the medical gentlemen demanded. The jury returned a verdict of "apoplexy."

It may hence become a matter of medico-legal inquiry to verify the existence of death, in cases where doubt prevails owing to the person being in a state of apparent death,—natural or assumed. The recent

[1] The Principles of Forensic Medicine, 3d edit., p. 540, Lond., 1827.

observations and experiments of M. Bouchut[1] lead him to conclude, that all varieties of apparent death, and especially such as are owing to syncope and asphyxia, however much their symptoms may differ, present the common character of the persistence of the heart's pulsation audible to auscultation. M. Bouchut's communication was laid before the *Académie des Sciences*, of Paris, who awarded him a prize for the same; and the commission to whom it was referred reported through M. Rayer, a great variety of additional observations made by them, which confirm the conclusion of M. Bouchut. He enumerates the certain signs of death under two divisions—immediate and remote. The *immediate* signs are—prolonged absence of the sounds of the heart; simultaneous relaxation of the sphincters; and sinking of the globe of the eye, with loss of the transparency of the cornea; the first of which is regarded by the commission as conclusive. The *remote* signs are—cadaveric rigidity; absence of muscular contractility under the influence of galvanism, and putrefaction.

Perhaps the most singular case on record of suspension of two of the most important of the vital functions occurred to John Hunter. In the year 1769, being then forty-one years of age, of a sound constitution, and subject to no disease except a casual fit of the gout, he was suddenly attacked with a pain in the stomach, which was speedily succeeded by apparently a total suspension of the action of the heart and lungs. By a violent exertion of the will he occasionally inflated the lungs, but over the heart he had no control whatever; nor, although he was attended by four of the chief physicians in London from the first, could the action of either be restored by medicine. In about three-quarters of an hour, however, the vital actions began to return of their own accord, and in two hours he was perfectly recovered. "In this attack," says one of his biographers—Sir Everard Home—"there was a suspension of the most material involuntary actions: even involuntary breathing was stopped; while sensation, with its consequences, as thinking and acting, with the will, were perfect, and all the voluntary actions were as strong as ever."[2]

At one period it was universally credited, that substances could be administered which might arrest the vital functions, or cause them to go on so obscurely as to escape detection. This erroneous popular notion is exhibited in the description of the action of the drug administered by Friar Lawrence to Juliet.

> "Take thou this phial, being then in bed,
> And this distilled liquor drink thou off;
> When presently thro' all thy veins shall run
> A cold and drowsy humour, which shall seize
> Each vital spirit: for no pulse shall keep
> His natural progress, but surcease to beat.
> No warmth, no breath, shall testify thou liv'st;
> The roses in thy lips and cheeks shall fade
> To paly ashes; the eyes' windows fall

[1] Abeille Médicale, No. 6, Juin, 1848.
[2] Ottley's Life of John Hunter, Bell's Med. Lib. edit. p. 38, Philad., 1839; and Hunter, On the Blood, by Palmer, Bell's edit., p. 189, Philad., 1840. In the latter work, Mr. Hunter refers to his own case.

Like death, when he shuts up the day of life;
Each part, deprived of supple government,
Shall stiff, and stark, and cold, appear like death:
And in this borrowed likeness of shrunk death,
Thou shalt remain full two-and-forty hours,
And then awake as from a pleasant sleep."

Romeo and Juliet, iv. 1.

Death may be feigned for sinister purposes. When the author was in attendance on the lectures of Mr. Brookes, the distinguished anatomist of London, a body was brought in a sack to the house, the vitality of which was detected by the warmth of a protruded toe. It was that of a robber, who had chosen this method of obtaining admission within the premises.

The celebrated case of Colonel Townshend exhibits the power occasionally possessed over the vital functions; and Dr. Cleghorn, of Glasgow, knew an individual who could feign death, and had so completely the power of suspending, or at least of diminishing, the action of the heart, that its pulsations were imperceptible.[1]

Lastly, the character of the death, as to violence or gradual extinction, is often exhibited in the physiognomy of the dead. Where it has taken place during a convulsion, or by agents that have forcibly and suddenly arrested respiration or innervation, the countenance may be livid, the jaws clenched, the tongue protruded and caught between the teeth, and the eyes forced, as it were, from their sockets; but usually in death from old age, or even from acute and tormenting disease, any distortion or mark of suffering that may have existed prior to dissolution subsides after the spirit has passed, and the features exhibit a placidity of expression singularly contrasting with their previously excited condition. For effect, however, the poet and the painter suit their descriptions of death to the character of the individual whom they are depicting.[2] The tyrant falls convulsed and agonized, whilst the tender and delicate female is described to have progressively withered, till

"At last,
Without a groan, or sigh, or glance to show
A parting pang, the spirit from her past;
And they who watched her nearest could not know
The very instant, till the change that cast
Her sweet face into shadow, dull and slow,
Glazed o'er her eyes—the beautiful, the black,—
Oh! to possess such lustre, and then lack."

Byron's *Don Juan*, canto iv.

Warwick's description of the frightful physiognomy of Duke Humphrey after death from suffocation exhibits some of this poetical license:—

"But see, his face is black and full of blood;
His eyeballs farther out than when he lived,
Staring full ghastly like a strangled man:
His hair uprear'd, his nostrils stretch'd with struggling:
His hands abroad displayed, as one that grasp'd
And tugg'd for life, and was by strength subdued.

[1] See, also, the case of the Hindoo, mentioned at p. 146 of this volume.
[2] Sir C. Bell, The Anatomy and Philosophy of Expression, 3d edit., p. 185, Lond., 1844.

Look on the sheets; his hair you see is sticking:
His well-proportioned beard made rough and rugged,
Like to the summer's corn by tempest lodged.—
It cannot be but he was murdered here:
The least of all these signs were probable."

King Henry VI., Part ii. Act 3.

How different is this picture from that of the countenance of the young being, who has gradually sunk to death in the manner above described. The beauty is unextinguished, and the paleness and lividity of death have taken the place of the colours of life; yet the wonted physiognomy may remain:—

"Hush'd were his Gertrude's lips! but still their bland
And beautiful expression seem'd to melt
With love that could not die!"

CAMPBELL.

Perhaps one of the most beautiful and accurate pictures, drawn by Byron, is his description of the serenity of countenance observable in most fresh corpses; an expression, which, by association, is deeply affecting, but not without its consolation to the friends of the departed:—

He who hath bent him o'er the dead
Ere the first day of death is fled;
* * * *
Before decay's effacing fingers
Have swept the lines where beauty lingers;
And mark'd the mild angelic air,
The rapture of repose that's there;
The fix'd yet tender traits, that streak
The languor of the placid cheek;
And but for that sad, shrouded eye,
That fires not,—wins not,—weeps not now;
And but for that chill, changeless brow,
Where cold obstruction's apathy
Appals the gazing mourner's heart,
As if to him it could impart
The doom he dreads, yet dwells upon:
Yes, but for these and these alone,
Some moments, ay, one treach'rous hour,
He still might doubt the tyrant's power.
So fair, so calm, so softly seal'd,
The first, last look by death revealed.

BYRON'S *Giaour*.

An easy death—euthanasia—is what all desire; and fortunately, whatever may have been the previous pangs, the closing scene, in most ailments, is generally of this character. In the beautiful mythology of the ancients, Death was the daughter of Night, and sister of Sleep. She was the only divinity to whom no sacrifice was made, because it was felt that no human interference could arrest her arm; yet her approach was contemplated without any physical apprehension. The representation of Death as a skeleton covered merely with skin on the monument at Cumæ was not the common allegorical picture of the period. It was generally depicted on tombs as a friendly genius, holding a wreath in his hand, with an inverted torch,—a sleeping child, winged, with an inverted torch resting on his wreath, or as Love, with a melancholy air, his legs crossed, leaning on an inverted torch,—itself

a beautiful emblem of the gradual self-extinguishment of the vital flame.[1] The disgusting representations of Death from the contents of the charnel-house would not seem to have been common until the austerity of the 14th century, and are beginning to be abandoned. In more recent times, Death has been portrayed as a beautiful youth, and it is under this form that he is represented by Canova, on the monument erected in St. Peter's at Rome, by George the Fourth of England, in honour of the Stuarts.

[1] D'Israeli, Curiosities of Literature, 2d Series, Amer. edit., vol. ii. p. 44, Boston, 1834.

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i. refers to the first, and ii. to the second volume.

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THE END.